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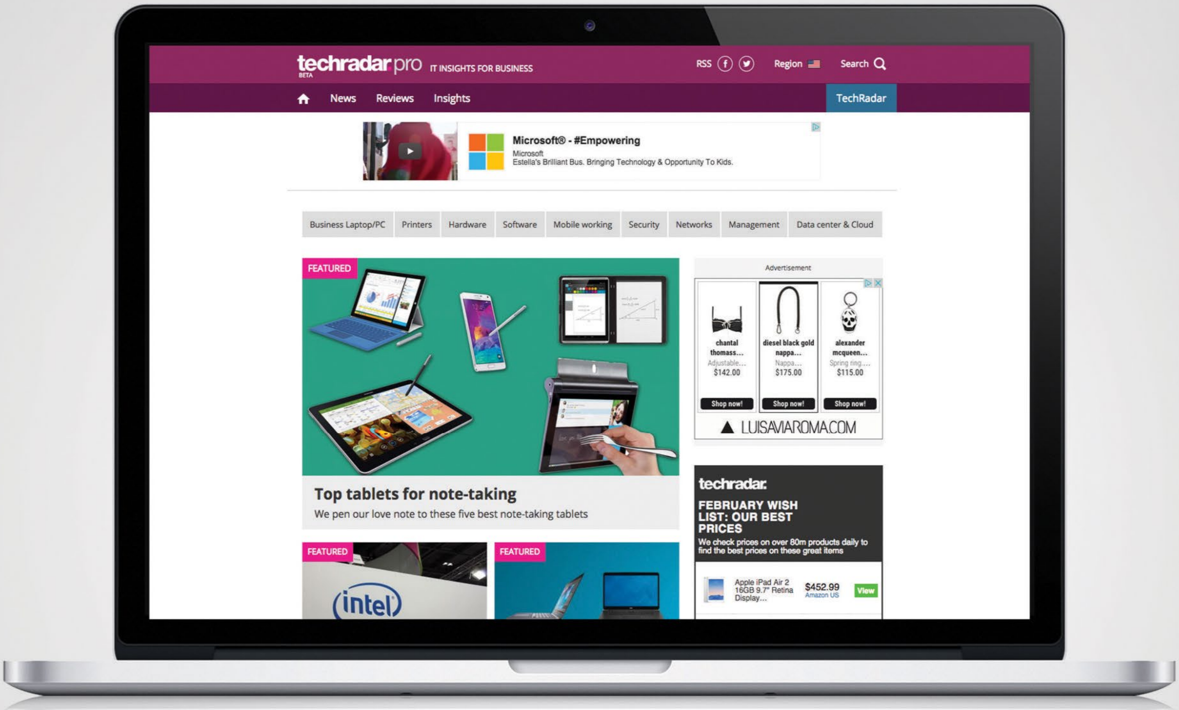

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Guy Cocker

LOUNGING AROUND

BEING A PC USER IS GREAT, but it can make you a bit of a solitary animal. I tend to work all day on my laptop with my intimidating-looking gaming headset on, and then when I get home, unwind until the early hours by playing games on my ultra-wide monitor.

That's one of the great things about PCs—you can use them anywhere and stay out of everyone else's way. But recently, I've been missing the days when I used to share an apartment and spend Friday nights playing sports games with my housemates accompanied by beers and pizzas.

This nostalgia led me to this month's cover feature, a couch gaming special for those who want to enjoy their PC gaming in a more relaxed setting. Unbelievably, it's been nearly two years since we last did such a special, in November 2020, the same month the PlayStation 5 and Xbox Series X hit the shelves. It's still nearly as difficult to get one of Sony's consoles today as it was back then, which is one of the reasons I feel it's pertinent to revisit the idea today. But really, this is about building a box that sits in your living room, looks good, stays quiet, and unlocks the many thousands of amazing gaming experiences that exist on the PC.

Yes, it can be expensive to build a living room PC, especially compared with a console, but as I found by building mine (page 16), it's a much more premium experience when it's done. You can install as many storage drives as your case can handle, play in higher resolutions, assisted by DLSS and FidelityFX Super Resolution 2.0, and enjoy proper ray tracing. You can also continue games started on your desktop or laptop, enjoy free multiplayer, get a free Epic Store game every week… the list of benefits goes on.

Our cover feature also covers the surprising amount of new and existing peripherals that are built for the couch gaming experience—wireless headsets that last for days, lapboards that allow you to use a keyboard and mouse, and soundbars with THX Virtual Surround. We've rounded up the best accessories available so that once you've got your couch gaming PC, you can make the most of it.

Away from the living room, it's starting to feel like we're tantalizingly close to a new generation of CPUs. In this issue, we look at AMD and what it has in store for its Zen 4 series, which should offer the PC world another leap forward and once again bring the fight to Intel in terms of pricing and performance. It's going to be quite a year for Team Red, and you can prepare yourself by heading to page 38.

Speaking of Team Red, Sam has put together an AMD-focused Build It this month (page 66). With the recent RX 6000 series refresh, FidelityFX Super Resolution 2.0 wowing in early titles like *God of War* and *Deathloop*, and Infinity Cache adding performance benefits to systems with AMD CPU and GPU pairings, I was really interested in this particular build. I hope you enjoy it.

I also want to give a personal thanks to Christian Guyton, who is leaving us for our sister publication, *TechRadar*. Christian made a big impression on the title over three years, and I know many of you enjoyed his technical knowledge, humor, and love of RGB. Please join me in wishing him all the best.

Enjoy the issue!

Guy Cocker

Guy is Maximum PC's Editor-in-Chief. He built his first gaming PC in 1997 to play Tomb Raider on 3dfx, and has been obsessed with all things PC ever since.

↘ submit your questions to: editor@maximumpc.com

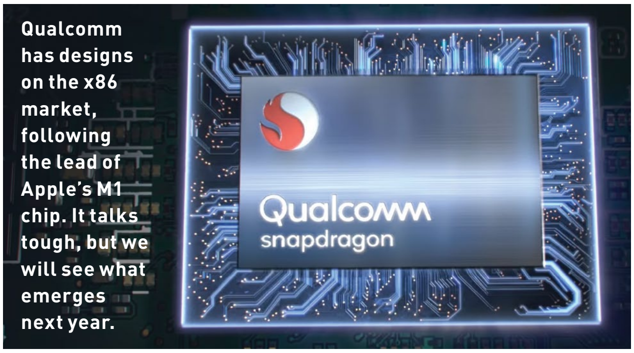
THE NEWS

Qualcomm aims for your desktop

Another ARM-based processor to enter the frame

IN JANUARY last year, Qualcomm spent $1.4 billion on buying Nuvia—that's a lot for a company barely two years old with few tangible assets. What Nuvia had was expertise in processor design, particularly ARM-based chips, and also several ex-Apple engineers in its ranks.

Qualcomm is a huge, but fabless, manufacturer of processors and other silicon. Its chips power about 30 percent of the world's smartphones and high-end Snapdragon SoCs are found in tablets and laptops. Apple's M1 chip has shown what could be done with a good ARM design. Qualcomm aims to build PC-level processors and take a bite out of the x86 market, starting with performance laptops but also becoming a proper desktop contender.


Qualcomm has designs on the x86 market, following the lead of Apple's M1 chip. It talks tough, but we will see what emerges next year.

Originally Qualcomm hoped to have a processor to rival Apple's M1 by the end of 2023. That now looks to have slipped to 2024, but Qualcomm is due to start testing samples this year. Its CEO, Cristiano Amon, claims Qualcomm is "aiming to have performance leadership in PC on the CPU". That includes Apple's M2 chip, as well as anything Intel or AMD produces.

Apple's M1 showed that the ARM-based processor can be a threat to the x86 orthodoxy. It offers some inherent advantages, mostly down to its simplicity, and they are a good fit for mobile devices where power efficiency is paramount. Its downfall is that you need to translate x86 applications, adding considerable drag to performance, though Apple and Microsoft have reduced that recently. Apple's own OS has supported three different chip architectures in its lifetime and is currently developing for its 64-bit ARM chips. The explosion of the smartphone market has added a lot of RISC-powered phones that needed apps to run. The days where you can develop solely for the x86 architecture are fading—half the world's browsing is now done on a RISC-based smartphone.

The x86 architecture has been around since 1978, and its days may be numbered. It's too complicated, there are messy legacy issues, and it can be a security nightmare. ARM-based designs or other similar RISC-based architectures have always been a tantalizing alternative. AMD once toyed with the idea of jumping ship before fully committing to x86 with the Zen core.

Others have tread this path before. PowerPC made a fair go, getting into Apple's machines and looking like a serious player for a while during the 1990s. Alpha processors were another RISC contender before Intel bought it and killed it off. Sun's SPARC managed to capture slices of the high-end server market and keep them for about 30 years, but it finally threw in the towel in 2017.

The x86 world has always looked vulnerable to being overthrown by RISC architectures, but nothing has come close yet. It's a robust, established market with a huge legacy of support and years of development from Intel and AMD waiting to come in the pipeline. Yet it faces a challenge from below.

What looks likely to change is the point where the ARM-powered devices end and x86 ones start, this currently (roughly) pivots around the level of the smaller and more basic laptops. You'll find Chromebooks running the full mix of processors from small ARM-based Cortex chips through to chunky 11th generation Intel silicon. It's a competitive sector, where the simplicity of ARM-based chips shines and that large installed base of mobile devices provide all the impetus the software developers need.

Qualcomm may be gunning for your desktop but it is likely to score better elsewhere—even if, as it claims, we'll see Windows PCs powered by Nuvia-designed Qualcomm SoC processors by 2024. If it can replicate the performance of Apple's M-series chips things will get interesting but nothing runs x86 applications and games as well as a native processor from the big two.

Qualcomm's entry into the field of play is a welcome one. It talks a good game, but then the M1 chip came as something of a surprise. **–CL**

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NEW BABY SURFACE

FASTER, LONGER-LASTING AND STILL AS THIN

MICROSOFT HAS A PATCHY RECORD with hardware, but its Surface laptops have been a success. It has just launched the Surface Laptop Go 2, an update on its most budget-friendly member of the Surface squad. The $599 laptop is in the competitive Chromebook territory. The changes are mainly on the inside of the aluminum/polycarbonate case with a Core i5-1135G7 processor, a four-core Tiger Lake chip with a base clock of 2.4GHz, and a maximum boost of 4.2GHz, with integrated Iris Xe graphics (that's $309 retail already). This is coupled with either 128GB or 256GB of solid-state storage, and 4GB or 8GB of RAM. The screen remains the same 12.4-inch touchscreen with a resolution of 1,536x1,024. Key travel is now 30 percent greater than a MacBook Air and we also get a new color (sage) and over 13 hours of battery life from the thinnest and lightest Surface laptop you can get. It's not a major update but it still looks pretty cool. **–CL**

WIN11 WITH NO MINIMUM

New preview build shows how easy it is

ONE ASPECT of Win11 that didn't go down well at launch was its hardware requirements, specifically for the processor. Needing a chip with TPM 2.0 support (Trusted Platform Module), which for Intel meant 8th generation silicon or better, left some capable processors out of luck. Of course, Win11 could run on 'older' machines, Microsoft just didn't want you to do it. But Microsoft has accidentally released a preview build of the 22H2 update, which has been offered as an upgrade to some people with Win10 rigs not signed up for the Insider program. Win10 Skylake and Kaby Lake systems have reportedly been upgraded to Win11 without issues. But, according to a Microsoft post, it was a bug—the hardware requirements have not changed and support won't be forthcoming. That's a pity, as the requirements of Win11 are artificially high and some relaxation would be welcome, although it's unlikely that Microsoft will change its mind. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

✓ **PLASTIC-EATING BUGS**
The larvae of a species of darkling beetle, the superworm, can break down styrofoam.

✓ **TSMC TO GO 2NM**
According to its roadmap, TSMC plans to have its 2nm nanosheet chips—a type of gate-all-around design—in production by 2025.

✓ **TINY ROBOT CRABS**
Engineers have built the world's smallest remote-control robots. These 0.5mm wide crabs can fit through the eye of a needle.

TRAGEDIES

✗ **TIDE TURNING**
Players are unhappy with the 'free' game *Diablo Immortal* as its loot box system makes it expensive to buff yourself up.

✗ **JAMES WEBB STRUCK**
A micro-meteoroid has hit the main mirror of the successor to the Hubble space telescope.

✗ **NO WINDOWS ON HDDs**
Some manufacturers aren't happy with Microsoft's plans to have Windows boot from SSDs only, and not HDDs, by 2023.

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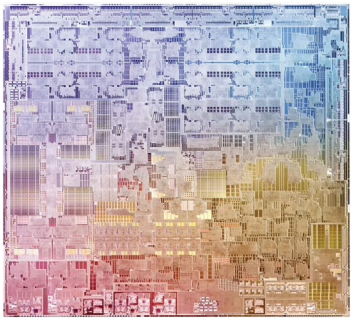


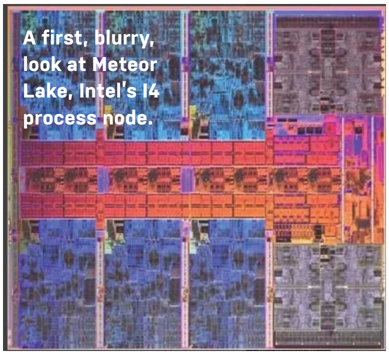
APPLE LAUNCHES M2 CHIP

4bn more transistors for second-gen silicone

WHEN APPLE RELEASED its M1 chip, the ARM-based design not only gave Apple independence but kept it dangerously competitive. Apple is now ready with round two. The M1 was a 5nm chip and TSMC isn't ready with 3nm yet, so the M2 is a tweak of the 5nm design with a similar transistor density. The M2 has 20 billion transistors, so it's physically bigger, but the basic pattern is the same: four performance cores, 16MB rather than 12MB of L2 cache, and four efficiency cores.

The M1 was blessed with 68GB/s of memory bandwidth but the M2 pushes that to 100GB/s. There's more actual memory too, with up to 24GB of LPDDR5 of Apple's Unified Memory Architecture. The GPU has been upgraded to ten from eight cores, pushing graphical performance up by a claimed 35 percent. The 16-core AI engine is now over 40 percent faster. Overall, Apple claims the M2 offers an 18 percent hike in performance over the M1 for the same power draw. It also easily outguns Intel chips on performance against power. This is a strength of Apple's M-series, Intel can keep up but needs wattage to do it. The M2 chip makes its debut in the new MacBook Air and 13-inch MacBook Pro.

Meanwhile, over in the M1 camp, researchers at MIT's computer lab have discovered an 'unfixable' security flaw, dubbed PACMAN. It involves Apple's pointer authentication codes, and the team has demonstrated that using speculative execution attacks it's possible to circumnavigate security measures. Essentially, it's a similar trick to the Spectre or Meltdown vulnerabilities from a few years back. Though potentially nasty, the flaw isn't easy to exploit in a meaningful way. Apple issued a statement saying that PACMAN "does not pose an immediate risk". So no worries then. **–CL**



A first, blurry, look at Meteor Lake, Intel's I4 process node.

INTEL SHOWS ITS NODES

Gelsinger's grand plan starts to take shape

INTEL'S PROBLEMS with its processor nodes have been notorious. It was slow to reach 10nm and got stuck there. But it got a new CEO, Patrick Gelsinger, and an ambitious plan to reclaim the leadership in CPU technology by 2025. To do that, it made a bold promise to make five new nodes in four years. The second step in that journey, Intel 4, or I4 (although comparable to TSMC's 7nm) is due to arrive in the shape of the Meteor Lake processor next year. We've seen actual silicon in the form of a die at this year's VLSI Symposium, which has been running since 1981 as a venue for engineers to show off technical stuff.

The I4 process is Intel's first to exclusively use EUV, Extreme Ultraviolet, lithography. According to Intel, it offers 21.5 percent higher frequencies for the same power or a 40 percent power reduction at the same frequency. Like Lakefield before it, Meteor Lake uses Foveros 3D packaging (stacking chips). It has a transistor density of around twice that of I7 (10nm as was), with six performance cores and eight efficiency cores. We've seen test wafers of its I3, 20A, and even a prototype 18A wafer recently, which Intel says is six months ahead of schedule. That bold boast appears to be on track and perfectly achievable.

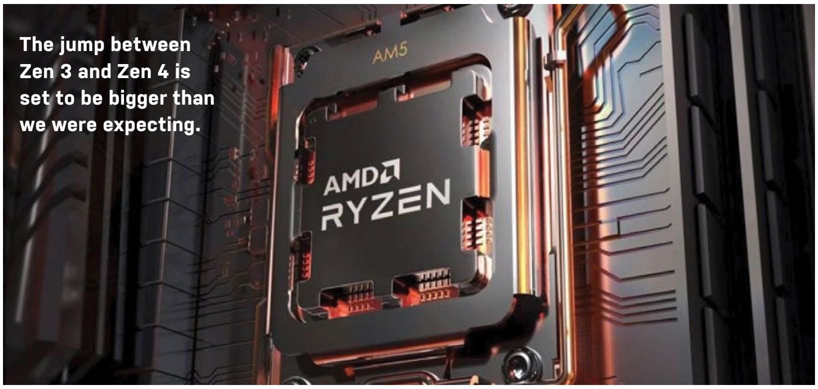
Before all this, we have Raptor Lake, due later this year. This uses the first node of the five promised. Engineering samples are in the hands of the usual suspects and we have the first benchmarks. For what they're worth, one chip has tested 20 percent faster than the i9-12900K. Intel is back, which would be bad news for AMD if that company wasn't doing rather well itself. The next few years are going to see fierce competition and rapid developments in CPU technologies, at a pace of around one generation a year. That can only be good news all round. **–CL**

Zen 4 will be 35 percent faster

AMD'S ANNUAL FINANCE DAY may sound irredeemably dull, but it's an opportunity to show something interesting, and AMD generally has something to crow about. This year, it was an architectural and process node roadmap, going all the way to Zen 5 in 2024, complete with a ground-up new architecture. However, of more immediate interest is Zen 4. We're used to AMD's Zen generations taking decent steps, but the jump from Zen 3 to Zen 4 is shaping up to be a good one.

AMD is expecting an Instructions Per Cycle (IPC) bump of eight to ten percent but has now said it expects an increase of over 15 percent on single-threaded performance, as well as a 25 percent boost in performance per watt. We'll also see 'significant' increases in clock frequencies and there have been demonstrations of Zen 4 chips running at 5.5GHz. Memory bandwidths also get a jolt with up to 25 percent on the bandwidth, thanks to the switch to DDR5, and double the L2 cache per core. Together, AMD is looking at an overall performance increase of 35 percent.

AMD is looking to repeat the magic it managed with the Ryzen 5000-series until Alder Lake came along. That 5.5GHz engineering sample managed to trounce an Intel Core i9-12900K at Cinebench by 31 percent. The first members of the Zen 4 family, named Raphael, are due this fall. These will be followed by V-cache versions, and more core-heavy server monsters in time, as well as a switch to a 4nm process. Companies are often pretty bullish about their products but AMD rarely disappoints. It seems that after a slight lull with Zen 3+, AMD is back in fighting form. **–CL**



The jump between Zen 3 and Zen 4 is set to be bigger than we were expecting.

Supercomputer goes exascale

The Dept of Energy at the Oak Ridge National Laboratory has fired up its latest supercomputer, Frontier. Three years in the making, it is the first to officially manage exascale computing—10^18 64-bit floating-point calculations per second (an ExaFLOP)—and has a theoretical peak performance of two ExaFLOPS. The magic is worked by a combination of HP's Cray architecture, 9,472 AMD Epyc 64C CPUs, 37,888 GPUs, and 700 petabytes of storage.

Frontier may not hold the crown for long. The Intel-powered Aurora (another DOE Oak Ridge project) should start testing soon, ready for deployment next year. It was due to be the first exascale supercomputer but was hit by delays in Intel's 7nm chips. **–CL**

Goodbye Internet Explorer

Microsoft has pulled support for Internet Explorer and will redirect the handful of people who still use it to Edge instead. IE was launched in August 1995, a few months after Netscape Navigator and five years after the web browser was invented. Part of every Windows installation, it quickly gained popularity, peaking at around 95 percent of the market. But Microsoft didn't keep pace with technological advancements and it was outclassed by Chrome in 2008. IE's market share evaporated and Microsoft switched focus to the Edge browser in 2015, which has hardly sparkled. Today, Chrome is the king of browsers; somehow Microsoft managed to lose the desktop browser wars. **–CL**

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Jarred Walton

TECH TALK

AMD's FidelityFX Super Resolution 2.0

LAST YEAR, AMD launched FidelityFX Super Resolution (FSR), an upscaling algorithm promising improved performance, possibly inspired by Nvidia's DLSS (Deep Learning Super Sampling). Rendering at a lower resolution then upscaling can boost performance, and is almost a requirement to play games at 4K and maxed out settings, especially with ray tracing.

FSR was a good first effort but it relied on spatial upscaling using only the data present within a single frame as input. It applied an upscaling and customized Lanczos sharpening filter, a relatively low overhead way of doing upscaling. However, artifacts were visible at higher upscaling factors and it did nothing to combat aliasing. DLSS uses temporal upscaling, with data from multiple frames combined with motion vectors and the depth buffer and feeding that into an AI enhancement algorithm. DLSS 2.x looked better than FSR but was restricted to Nvidia's RTX graphics cards.

Enter FSR 2.0, an overhaul of the algorithm that has more in common with DLSS than it does with FSR 1.0. It also uses temporal upscaling and applies anti-aliasing to the resulting output, like DLSS but unlike FSR 1.0. The key difference is that AMD feeds all this into a hand-tuned upscaling algorithm that doesn't require any specialized machine learning hardware. That means FSR 2.0 can work on just about any modern GPU.

Based on our testing, it should work on any DirectX 12 compatible GPU; but the results might not be as promising with low-end hardware. We tested FSR 2.0 using *Deathloop* on multiple generations of GPUs from AMD and Nvidia, from the latest Ampere and RDNA 2 GPUs through Turing, RDNA, Vega, Pascal, Polaris, and even Maxwell. It worked on every one. We even tested it with Intel's Iris Xe graphics (Tiger Lake) and the previous generation Iris Plus graphics (Ice Lake). It worked in both cases, though the results weren't great. Going from 11 fps to 14 fps with the Ice Lake Gen11 graphics might represent a 25 percent boost in framerates at 720p, but it's still unplayable.

How does FSR 2.0 look? With a sample size of just one game, image quality looked phenomenal. There are now three upscaling modes: Quality, Balanced, and Performance. It was hard to tell the difference between Quality mode and native rendering and, in fact, some of the sharpening and anti-aliasing applied with FSR 2.0 makes for a more pleasing image than native rendering with TAA and a sharpening filter. FSR 2.0 and DLSS were close enough so it was hard to tell the difference. Using higher upscaling factors, particularly at lower resolutions, image quality takes a hit, but at 4K in Performance mode (1080p upscaled to 4K) it still looks good.

***Deathloop* was the first game to get FSR 2.0 and more are in the pipeline.**

© BETHESDA SOFTWORKS

FPS improvements were decent, with typical gains of around 25 percent at 1080p, and up to 60 percent at 4K using Quality mode. Performance mode at 4K delivered close to double the FPS, provided the GPU had enough VRAM to make 4K rendering viable.

It's a great start for FSR 2.0 but we need to get the technology in more games. Intel's XeSS hasn't officially launched but will leverage either Intel Arc's Matrix Engines or use DP4a for non-Arc GPUs. Nvidia recently released its Streamline API, which aims to make integration of upscaling support easier for developers, and it should work with DLSS, FSR 1.0/2.0, XeSS, and future algorithms. Hopefully, it means games that offer a choice of algorithms rather than only supporting one solution.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE TOP FIVE CAPTURE CARDS

WHILE NVIDIA AND AMD'S increasingly sophisticated capture software can do a fantastic job of livestreaming or recording your gameplay prowess for the world to see, if you're taking things seriously, you'll probably still need a capture card. That's because you'll either want to have a dedicated computer to take care of the recording and mixing for a professional look, or you might just want to play a console game now and again. This varied list of cards, covering a range of prices, resolutions, and card type, allow you to do just that.

NZXT
TYPE-C
IN
OUT

5

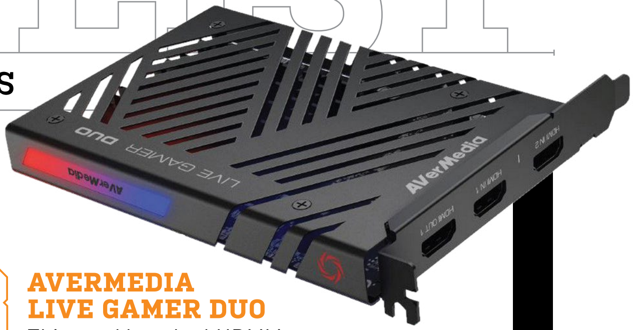
NZXT SIGNAL 4K30

NZXT may be late to the capture card game, but its newly-released Signal 4K30 looks to offer the company's usual level of quality. It will capture in 4K30 and integrates with NZXT CAM software to ensure picture accuracy in your streaming software of choice such as OBS. A cheaper HD60 version is also available for $40 less. **$180, www.nzxt.com**

4

EVGA XR1

With a volume wheel on top of its body, this EVGA is certainly distinctive. That's because its USP is a built-in audio mixer, allowing you to drop your mic volume during cut scenes and bring it back in when you want to commentate. Audio levels are visible, thanks to the RGB lighting on top. It maxes out at 4K30 capture, which should be enough to satisfy most people. **$100, www.evga.com**



3

AVERMEDIA LIVE GAMER DUO

This card has dual HDMI inputs on the rear. Why? So that you can mix two feeds at once, of course. You might want to use an SLR camera for the pro streamer look or stream yourself building a PC with one camera on you and another on your build. It may only capture up to 1080p60 HDR, but this is one versatile card. **$219, www.avermedia.com**

2

ELGATO 4K60 S+

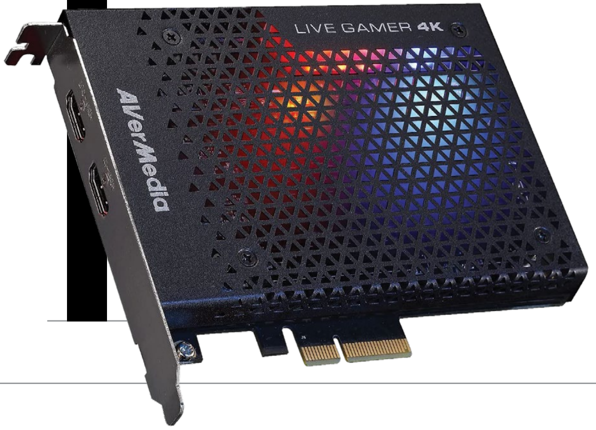
Elgato's portable capture card is expensive, but it allows you to record 4K footage wherever you go. That's because it can be used on its own, no PC required. It will capture 4K60 HDR footage directly to an SD card, and you can even plug in a microphone to record commentary as you play. Time to buy that 1TB SD card. **$399, www.elgato.com**

4K60 S+
SD
REC
IN

1

AVERMEDIA LIVE GAMER 4K

If you're a desktop user with a spare PCIe slot, this 4K capture card from AVerMedia is worth looking at, thanks to its raw power, RGB lighting, and competitive price tag. The Live Gamer 4K will capture and pass through most resolutions up to 4K HDR, meaning your viewers get footage so good it will make them weep with jealousy. **$195, www.avermedia.com**



© AVERMEDIA, ELGATO, EVGA, NZXT

Jeremy Laird

TRADE CHAT

GPU prices come back down to Earth

***ABOVE:* Nvidia's 3090: The last of the megabucks graphics boards?**

© NVIDIA

WHEN IT COMES TO PRICES, good news stories are hard to come by right now. Ironically, the one exception is graphics cards, which are now returning to RRP—albeit the recommended pricing is still pretty painful. But contrary to expectations of higher prices, there is reason to think that trend could be reversed. Cheap GPUs for everyone? If not this year, then maybe next.

The hard data here comes courtesy of Nvidia. Of course, Nvidia isn't going to publicly say that graphics card prices are going to be slashed, and nor is that likely to happen. But there were some telling tidbits in Nvidia's latest quarterly investors conference call that suggest the recent trend of falling prices is only going to continue.

Firstly, attached to the call was an official Nvidia statement that said, among other things, "the reduced pace of increase in Ethereum network hash rate likely reflects lower mining activity on GPUs". Which was Nvidia's roundabout way of conceding that the whole crypto mining thing on GPUs has gone quiet.

Nvidia has form when it comes to referring euphemistically to its mining-related GPU sales. In May this year, Nvidia paid $5.5 million to the Securities and Exchange Commission for failing to adequately inform investors about the scale of its sales to cryptocurrency miners. So, when Nvidia obliquely refers to "lower mining activity on GPUs", the implications are probably pretty epic.

If that sounds hyperbolic, Nvidia also provided some more specific indications that point toward falling GPU sales. At the risk of getting into the weeds with investor data, Nvidia says it sold $3.6 billion of gaming hardware in the most recently reported quarter, most of which were GPUs. It's expecting to trim that to $3.1 billion for the next quarter and go lower still for the quarter after that.

> It was a perfect storm of demand for graphics cards. Now it looks like it's going into full reverse.

What's remarkable, of course, is that Nvidia is predicting those dipping GPU sales despite the fact that it is planning on launching a brand new range of GPUs later this year. The bottom line? Demand for GPUs is falling off dramatically.

Partly, it's because crypto mining is less profitable than before, killing a huge chunk of demand stone dead. But with the world economy looking shaky, you'd expect demand from gamers to weaken. In other words, what's currently unfolding is precisely the opposite of the past 18 months.

During that period, demand from miners and gamers rocketed in parallel. Mining was becoming more profitable, while gamers were keen to get their hands on new GPUs. Partly because the latest hardware at the time delivered a particularly big jump in performance, generation over generation, but also because the pandemic meant a lot more stay-at-home activity, which for some meant investing in a better GPU was more worthwhile than ever.

It was a perfect storm of demand for graphics cards that was never going to last. And now it looks like it's fully going into reverse. Exactly what will happen, and when, with graphics card pricing remains difficult to predict. For instance, how will Nvidia's upcoming RTX 4000 series GPUs, and indeed AMD's Radeon RX 7000 family, be priced? My guess is that they will start out at around the level the RTX 3000 and RX 7000 left off, but will drop over the life cycle and that the generation that follows will actually be priced lower.

When I say lower I mean in real, inflation-adjusted terms. The way things are going with inflation right now, the dollar figure staying the same over the next couple of years would mean a real-terms 20 percent drop. But I have a feeling that a couple of years from now, the headline figure could actually be a little lower, segment by segment, for GPUs. Which would mean a pretty hefty real-terms drop.

If that's a bit speculative, what's certain is that all the indications are that the party is over when it comes to Nvidia and AMD selling as many GPUs as they can make at almost any price they care to name. Graphics is coming back to gamers. And about time, too.

Six raw 4K panels for breakfast, laced with extract of x86... Jeremy Laird eats and breathes PC technology.

DOCTOR

THIS MONTH THE DOCTOR TACKLES…

> Partitioning problem
> Slow flash drive
> Firefox annoyance

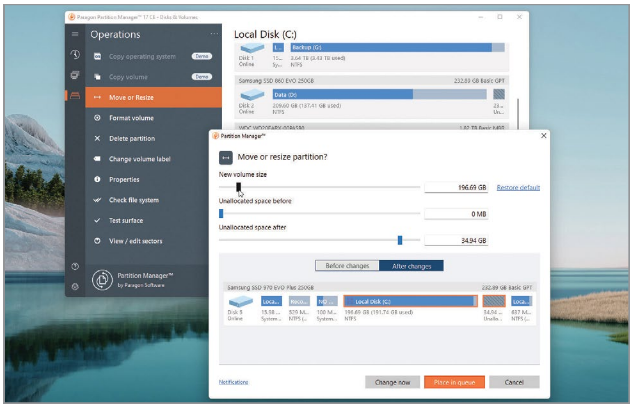
Save old PC!

I have a PC that I love very much (my first build), but it's not compatible with Windows 11, so after 2025, this machine will die. Can you suggest what to do with it? I don't want to sell it, so maybe start with Linux? NAS? Any ideas?

The spec is: Intel i5-6500 3.20GHz, MSI B150 GAMING M3, 16GB DDR-4 RAM, 520 GB SDD, 1TB Seagate, Radeon R9 390. Thanks in advance. **—Cesar Rosadio**

THE DOCTOR RESPONDS: That's a decent spec that should last well beyond 2025, Cesar. The Doc would shy away from using your PC as a NAS, as it's not optimized for 24/7 use—and consider the cost of running such a power-hungry machine around the clock! The most logical option is Linux, which should run until your PC reaches the end of its natural life.

The choice, of course, is which Linux to plump for. There are a mind-boggling array of distros to choose from, many of the derivatives of the big boys. The Doc suggests going down the Debian-based route to explore options based on the biggest Debian derivative of all, Ubuntu.


Paragon Partition Manager™ 17 CE - Disks & Volumes
Operations
Copy operating system
Demo
Copy volume
Demo
Move or Resize
Format volume
Delete partition
Change volume label
Properties
Check file system
Test surface
View / edit sectors
Partition Manager™
by Paragon Software
Local Disk (C:)
Backup (G:)
Disk 1
Online
3.64 TB (3.43 TB used)
NTFS
Samsung SSD 860 EVO 250GB
232.89 GB Basic GPT
Data (D:)
Disk 2
Online
209.60 GB (137.41 GB used)
NTFS
Partition Manager™
Restore default
Before changes
After changes
Samsung SSD 970 EVO Plus 250GB
232.89 GB Basic GPT
Disk 5
Online
Local Disk (C:)
196.69 GB (191.74 GB used)
NTFS
Notifications
Change now
Place in queue
Cancel

Move or resize partition?

New volume size 196.69 GB

Unallocated space before 0 MB

Unallocated space after 34.94 GB

Use a third-party tool to free space on your system drive.

Which one to choose though? The good news is that most Linux distros are engineered to be run directly from DVD and flash drive prior to being permanently installed, so you'll be able to road-test many of them before committing to one.

In fact, why wait until 2025? Get the ball rolling now by trialing Linux distros via live media—flash drives are much snappier than DVD, and if you have a spare 64GB or 128GB you can easily switch between distros by installing a tool like Ventoy (https://ventoy.net/), which allows you to copy the ISO files in a group to the drive, then switch between them from a boot menu.

If the choice out there is overwhelming, the Doc has a few distros you might want to consider. Start with Ubuntu 22.04 LTS—this Long Term Support version is supported for up to ten years, and new LTS builds arrive every two years instead of six months, as is the case with regular Ubuntu. This 'vanilla' version is better supported than any variant by virtue of its popularity.

If Ubuntu doesn't float your boat, then Linux Mint's Cinnamon desktop is a good alternative for Windows switchers (see www.linuxmint.com for details), as is System 76's Pop!_OS (https://pop.system76.com/), which aims to keep Linux as simple and streamlined as possible.

Another Ubuntu variant to consider is Elementary (https://elementary.io/), which does for macOS what Mint does for Windows.

If you find a variant you like and have space on your SSD, then investigate dual-booting Linux with Windows. We covered dual-booting Elementary and Windows back in our June 2017 issue.

Can't shrink system drive

I'm trying to dual-boot Windows 10 and 11 on the same drive—a 1TB NVME drive with 700GB free. I've tried shrinking the Windows 10 system drive to free up 500GB of space using Disk Management, but it can only free up to 100GB. What's going on, and how do I get around this? 100GB won't be enough for my Windows 11 needs! **—James Pelton**

THE DOCTOR RESPONDS: The reason Disk Management can't give you access to all the available space on the drive is that it doesn't reboot Windows during the partitioning process. As a result, it's unable to handle unmovable files such as paging files. These usually reside near the end of the volume so they stay out of the

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↘ submit your questions to: doctor@maximumpc.com way of other file operations to prevent disk fragmentation. Windows judges available free space from where this last file ends.

You may find after a couple of reboots Windows rearranges the files in such a way as to allow the drive to be shrunk, but a quicker and easier option is to make use of a third-party partitioning tool, which reboots during the resizing process to get around the issue of where files are stored on the drive. This allows files to be removed or rearranged to free up to 100 percent of the reported available space.

Paragon Partition Manager Community Edition (www.paragon-software.com/free/pm-express/) is free for personal use. On our test system—a 230GB system drive with around 35GB free space—Paragon shrunk the partition by the full amount after Windows' Disk Management tool said only 2.4GB could be freed up.

Firefox download behavior

Since updating Firefox, I find that when I click on a link to download a file attachment such as a PDF, instead of asking me where I'd like to save it, Firefox downloads it to my Downloads folder and then opens it—I can click the download button from here to save a copy easily enough, but I'm still left with the original download cluttering up my Downloads folder. Can I stop this unwanted action on Firefox's part?

—Steven E Cummings

THE DOCTOR RESPONDS: Open Firefox's settings and scroll down to the Applications section on the General tab. You'll see that Firefox can be configured to behave differently depending on the file type being opened. Scroll down to the Portable Document Format (PDF) entry and click the 'Open in Firefox' drop-down menu to instruct it to save the file automatically (select 'Always ask you where to save files'), ask you whether you want to save or open it, or select a different application to open the file—either the Windows default or your choice.

Painfully slow flash drives

I have an issue when copying files to flash drives. It doesn't matter whether I'm moving files from an SSD data drive or flash drive to another flash drive. The transfer rate starts out decent enough but drops off after a few minutes to almost zero.

I have three identical SanDisk Ultra Flair USB 3.0 256GB flash drives (model number SDCZ73-256G-G46), and whether I use USB 2.0, 3.0, 3.1, or any combination—it still dies. The platform is an Aorus X470 Gaming 7 WiFi V1.1, Ryzen 7 2700X, with 32GB of RAM. BIOS is F7. The cores aren't overloaded and the temps are in the 40s.

I've looked at the processes running and the CPU is hardly getting above a few percentage points. I've tried closing Kaspersky, but no joy. I'd appreciate some thoughts as to what may be going on! **—Ken St John**

THE DOCTOR RESPONDS: Fluctuating write times are nothing new, of course, and everyone has experienced how a single 16GB file transfers far more quickly than 16GB data spread across lots of files. This is especially true for USB flash drives. In 2011, *Tom's Hardware* conducted a group test of the nine fastest USB 3.0 flash drives (see www.tomshardware.com/reviews/usb-3.0-thumb-drive-flash-drive%2C2900.html), which revealed drives capable of writing 46MB/s when handling large files dropped to below 0.5MB/s when copying lots of small files.

This variation continues today, as confirmed by a quick glance at user-submitted benchmarks for USB drives at https://usb.userbenchmark.com where even the best-performing drives, such as the SanDisk Extreme, vary widely with their write speeds.

There's also no one-size-fits-all approach to flash drive technology. While the USB bus—whether 2.0, 3.0 (sorry, USB 3.2 Gen 1), 3.2 Gen 2, or USB 3.2 Gen 2x2—obviously determines how fast data can be transferred, the onboard USB controller also plays a role along with the speed of the hardware bus your USB ports are on.

There's also the question of the flash memory being used—over the years, manufacturers have moved from NAND to 3D NAND flash memory, and now drives are appearing that contain elements of SSD technology to further boost performance.

Manufacturers rarely reveal the nuts and bolts of each model but as a rule, the more you pay—particularly when comparing drives from the same manufacturer—the more performance you should expect. In Ken's case, the SanDisk Ultra Flair costs significantly less than SanDisk's new top-of-the-line model, the Extreme Pro ($60 for the 256GB model, https://www.amazon.com/dp/B08GY3Z4JR), which uses SSD technology to deliver faster speeds, in theory.

At first glance, the Extreme Pro's superiority is borne out by the benchmarks, as it easily outpaces the Ultra Flair in all metrics, including the crucial peak random write speeds: 11.9MB/s versus the Ultra Flair's pedestrian 2.7MB/s. But just as we were about to steer Ken towards this drive, we noticed some disturbing reports among customer reviews. There were reports of drive failures, while others have noticed how the impressive read/write times fall away after a small amount of data (200-250GB) has been transferred to the drive.

Solid-state flash drives are quicker than regular ones.

© WESTERN DIGITAL

It's been theorized that the Extreme PRO's lack of TRIM or UASP support explains the drop-off in transfer speeds, which see its overall write speed halved as fluctuations between the minimum and maximum write speeds increase. But, even after it loses this initial sheen, you should still enjoy faster and more consistent transfers than with the Ultra Flair.

If the negative reviews of the Extreme Pro spook you, the Doc suggests ditching flash drives altogether and trying an ultra-portable SSD like Samsung's T5 ($79 for 500GB, www.amazon.com/dp/B073GZBT36/) instead. You'll have all the benefits of SSD performance with TRIM support to ensure write speeds are consistently fast.

Gpedit.msc tip

Nick Peers correctly states that gpedit.msc is not available by default in Home editions of Windows (June 2022), but it can be done. One source is www.itechtics.com/enable-gpedit-windows-10-home—perhaps *Maximum PC* readers would like to know this. **—Jerry Bell**

THE DOCTOR RESPONDS: Great find, Jerry! We're happy to share the tip, which reveals how to add the Group Policy Editor (gpedit) in one of three ways: via the command prompt, a PowerShell script, or by downloading a third-party alternative, Policy Plus, which has one advantage over the Windows tool in that it includes a search feature.

You can download Policy Plus directly from https://www.itechtics.com/?dl_id=61—it's a portable file, so unzip it and double-click Policy-Plus.exe to run it directly. It runs in Windows 10 Pro, so worth investigating if you're looking for a more powerful way to edit Windows policies. ⏻

LIVING ROOM LEGEND

Want to play your Steam library from the sofa on a console-sized PC? *Guy Cocker* has all the components, accessories, and build info you need for leaned-back bliss

THERE ARE BENEFITS to gaming in the office or study. You're less likely to disturb anyone, your RGB-enabled full-size case can be tucked under a desk, and you have a flat surface for keyboard and mouse-based games. But as console gamers will attest, the couch is better for playing with friends, immersing yourself in *God of War*, or getting comfortable for a weekend of laid-back gaming. That's why we wanted to create the perfect couch-based PC gaming experience and help mere mortals become living room legends.

The challenges are multiple—it needs to be compact enough to fit under the TV or in an AV cabinet and quiet enough not to distract from the gaming. Of the few cases built for this purpose, nearly all use the most compact motherboard size, mini-ITX—that means a cramped build where finger dexterity is key and a long magnetized screwdriver is a must.

Our accessories also have their own demands; they need to be wireless, so they don't create a web of cables. They need to have a good range, in case the PC is stored out of sight. And they need an excellent battery life so they can withstand long gaming sessions.

We're excited about this build and cannot wait to get an Xbox Series X-style gaming PC in our AV rack and spend a weekend playing games and hosting friends. Let's start by going through the components we've chosen.

© ELECTRONIC ARTS

INGREDIENTS

PART		RRP/STREET PRICE
CPU	Intel Core i5-12600K	$280
GPU	Asus GeForce RTX 3070Ti 8GB TUF GAMING OC	$700/ $900
RAM	Corsair Vengeance 32GB (2 x 16GB) 4800MHz DDR5 C40	$235
Mobo	Asus ROG STRIX Z690-I GAMING WIFI	$410
OS Storage	Samsung 980 Pro 1TB	$155
Game Storage	Corsair Force Series Gen.4 PCIe MP600 2TB	$240
Case	NZXT H1 v2	$399
PSU	NZXT 750W	$N/A
CPU Cooler	NZXT 140mm integrated AIO cooler	$N/A
OS	Windows 11 Home	$20
TOTAL		**$2,439 / $2,639**

PRICES CORRECT AT TIME OF PRINTING

WHAT'S IN THE BOX?

INTEL® CORE™ i5
i5-12600K
SRL4T

CPU

INTEL CORE I5-12600K

"The new gaming champ" is what we called the Intel Core i5-12600K in our January 2022 review, before awarding it a much sought-after 'Kick-Ass!' award. That's a strong recommendation for any couch gaming system, providing plenty of grunt for general tasks but crucially enough power to keep up with our chosen graphics card in games.

- ***RRP: $280* • *Street price: $280***

CPU Cooler

NZXT 140MM INTEGRATED AIO COOLER

NZXT's case comes with a CPU cooler pre-installed into the chassis. NZXT's cooler looks like a high-quality offering, and although it lacks RGB lighting, it does have perfectly-measured tubing lengths so there's no slack inside the case, as well as brackets for both AMD and Intel chipsets. The system only includes two 140mm fans overall, one for intake and one for exhaust, which isn't a lot of airflow if you intend to push your components.

- *RRP:* $N/A
- *Street price:* $N/A

Motherboard

ASUS ROG STRIX Z690-I GAMING WIFI

Intel was kind enough to loan us this fabulous Asus ROG STRIX board. It's packed with every feature you need, but the downside is that it's expensive at $410. If you want to save money, ASRock's Z690 Phantom Gaming-ITX is over $100 cheaper, while B660 boards such as the Asus ROG STRIX B660-I GAMING WIFI are available for half the price at $220, although bear in mind they don't support overclocking. This board justifies its price tag with DDR5 memory support, dual SSD slots, and Wi-Fi 6E.

- *RRP:* $410 • *Street price:* $410

CORSAIR
MP600 Gen4 PCIe

Game Storage

CORSAIR FORCE SERIES GEN.4 PCIE MP600 2TB

To add more storage for Steam games, we managed to repurpose a drive we'd used in an April 2022 build. Corsair's drive is a PCIe 4.0 drive, but it's not as fast as the Samsung in terms of read and write speeds, clocking in at 4,950MB/s for read compared to the theoretical max of 7,000MB/s for the 980 Pro. It should still be great for games though. If you're building at home, you might also want to consider just one 2TB M.2 SSD or using a SATA drive for the storage of your games. Either option will be cheaper on a per terabyte basis.

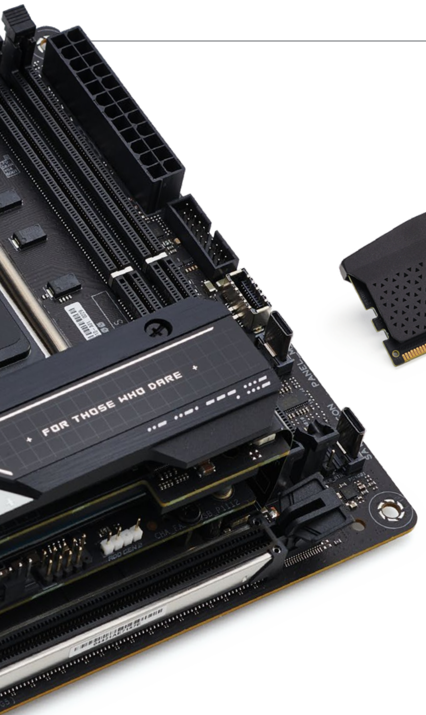
- *RRP:* $240 • *Street price:* $240

GPU

ASUS GEFORCE RTX 3070TI 8GB TUF GAMING OC

While we'd love to shove an Nvidia RTX 3090Ti in our build for 4K gaming, Nvidia recommends a power supply of 850W, which is above this case's supplied 750W PSU. We think our 3070Ti will be the right card for most living room gamers—it's got enough grunt to play the latest games in 1440p at high settings but it doesn't break the bank. This Asus is overclocked for performance, stays within the confines of NZXT's power supply, and fits neatly inside the case.

- ***RRP: $700***
- ***Street price: $900***



VENGEANCE
VENGEANCE

RAM

CORSAIR VENGEANCE 32GB (2X 16GB) 4800MHZ DDR5 C40

Our RAM choice was dictated by the motherboard—it's a DDR5 model, so we need to go with newer RAM. We used a Corsair Vengeance 32GB kit, which has dropped in price recently and doesn't boast needless RGB. Bear in mind that mini-ITX motherboards only have two memory slots, so you can't go adding more later. In that case, you'd need to replace them.

- *RRP: $235* • *Street price: $235*

PSU

NZXT 750W

NZXT's dinky power supply is a 750W model, which is enough for all but the most power-hungry graphics cards and processors. It sits at the top of the case, which keeps it out of the way of the motherboard and GPU. The cables come pre-installed, but the modular design means you can remove any you don't need to keep everything nice and tidy inside the case.

- ***RRP: $N/A*** • ***Street price: $N/A***

OS Storage

SAMSUNG 980 PRO 1TB

The 980 Pro is a PCIe 4.0 drive, which should max out the speed of the motherboard. The only downside is that, realistically, the 1TB size isn't big enough for a games-focused machine. Thankfully, our motherboard, while compact, still has a stacked M.2 drive design that allows you to install two drives at a time, which we took advantage of with our second drive (see opposite).

- ***RRP: $155*** • ***Street price: $155***

V-NAND SSD
980 PRO
PCIe 4.0 NVMe M.2
SAMSUNG
1TB

TUF GAMING
FORCE RTX
ASUS

Case

NZXT H1 V2

The star of the show in this build is the NZXT H1 v2, an ultra-compact mini-ITX case that bears an uncanny resemblance to the Xbox Series X. Alas, it's not quite as small as Microsoft's console, but it's still compact for a PC. It's available in both black and white color schemes and comes with both a CPU cooler and power supply. While the extras don't completely justify the high price, it does make things simpler when building.

- *RRP: $399*
- *Street price: $399*

HEAD IN THE GAME

BUILD YOURSELF A COMPACT, CONSOLE-LIKE LIVING ROOM GAMING PC.

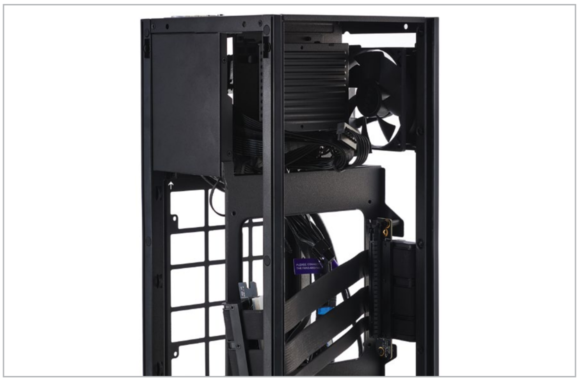
LENGTH OF TIME: **4-5 HOURS**

LEVEL OF DIFFICULTY: **MEDIUM**

GEFORCE RTX
NZXT

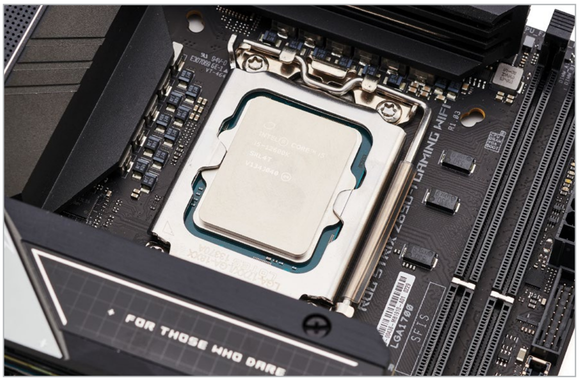
1 WHAT'S IN THE BOX?

WE STARTED THE BUILD by tearing into the NZXT H1 v2 box to see what we were dealing with in terms of design and space. First impressions are great—the case easily and neatly comes apart with a back panel and glass panel that easily pop off, then a U-shaped chassis that lifts off the top. All of the case's accessories are stored inside the case itself in a box sitting where the GPU will go. Other gaps in the case are protected by polystyrene blocks, giving you the confidence that the case has been protected since it left the factory. That first impression is soured somewhat by NZXT's short instruction manual that's light on details. Undeterred, we instead decide to just whip everything out to give us some room to build in.



4 BRAIN DRAIN

WITH THE CASE OPEN and gutted, it's time to get as much as we can fitted to the motherboard while it's outside of the case. Our first impression of the motherboard is fantastic—it's a beautifully made and sturdy board, but the sheer thickness of it (in particular the stacked M.2 slot design) makes us worried that it won't fit in this case. Nevertheless, we trust that NZXT has measured its case correctly and carry on as planned. The first step is to unhook and lift the retention arm over the CPU socket, remove the plastic covering, and grab our Intel Core i5-12600K. Align the chip so that the small arrow is in the bottom left corner, and then pull the retention arm back down and lock it into place to secure the CPU. Simple!



2

MAX PC UNPLUGGED

THE FIRST THING we removed was the PSU, which is pre-screwed into the case. With the PSU freed, the next step is to take out the modular power cables. This was actually much easier than it looks in the photo below. NZXT's case is really well designed, with a panel just behind the cables housing the case's fan controller, which folds neatly outward to give you more space to pull cables out. You might not need some of the power cables if, like us, you aren't installing any SATA drives. This is where the compact size of the case is a bonus though—all the components are so close together that the cable lengths are really short, so there's not a lot of excess cabling you need to manage.

NZXT
REMOVE SCREWS POINTED BY ARROWS AND LIFT TO OPEN
CHECK FOR CABLE AND TUBE CLEARANCE WHEN CLOSING
DO NOT FORCE SHUT

3

RADIATOR REMOVAL

WHILE IT'S GOOD to get the PSU out, removing the radiator and fan from within the case is going to have a real impact on the difficulty of this build. Again, full credit to NZXT here for making the radiator installation super easy thanks to a door that hinges outward, making it really easy to remove the rad and install the motherboard later. Four screws attach the radiator to this door, and another two secure the door in the case, with the latter screws staying put in the case so they don't get lost, which is another considerate touch from the manufacturer.

5

DUAL WIELDING

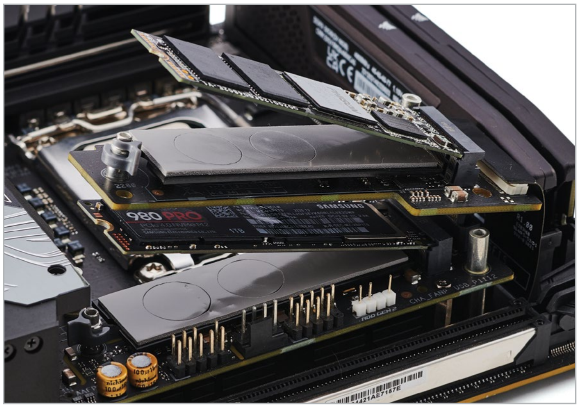
NEXT UP IS memory, and with this being a compact mini-ITX motherboard, there are only two slots for the RAM. That's not a big issue for most people, but it did push us into making the decision to install 32GB of RAM, rather than 16GB. The lower amount of memory would be fine for most games, but the compact nature of this machine means we don't really want to be opening it up again anytime soon if we need to upgrade it, for example, if 32GB becomes necessary down the line. It's a DDR5 motherboard, so we had to get the more expensive RAM, although we're encouraged to see prices falling on the newer memory. We also forgo RGB RAM, simply because you wouldn't really see it in the case.

FOR THOSE WHO DARE
VENGEANCE

6

TIME FOR A SANDWICH

BOY, WERE WE IMPRESSED with the elegant storage solution on this board. The M.2 slots are stacked on top of each other and then sandwiched between layers of heatsinks. We'd originally planned to use an Adata XPG GAMMIX S70 2TB drive kindly loaned to us by our friends at *PC Gamer*, but it was a pre-installed heatsink version, which was quite fiddly to remove from its casing. After scouring the stock cupboard, we found two SSDs that fit the bill nicely—a super-fast Samsung 980 Pro 1TB for Windows, and a slower (but still fast) Corsair MP600 2TB for games storage. We unscrewed the multitude of screws holding the sandwich together, kept them safe, and prepped the drives.



7 KEEPING COOL

ONE QUICK NOTE HERE: if you're using this motherboard, be sure to put your system drive on the top layer (marked M.2_1). We did it the other way around and found out in testing that it was limiting the speed of the Samsung 980 Pro SSD to around 1751MB/s read speed, less than a third of what it should be. But, back to the build, and make sure to take the plastic covering off the underside of the heatsinks on the board, which can be easy to miss. Also, keep the small screws together ideally on a magnetized dish, and pay attention during the opening phase, as it's easy to forget just how it all fits back together.

FOR THOSE WHO DARE
STRIX
ROG

8 SMALL HANDS

WE CAN'T SAY WE'VE been looking forward to working in such a tight space, but we can't put it off any longer—it's time to drop the motherboard into the case. There's only one way to screw the mobo in thanks to the pattern of the screw holes, but you need to angle the board into the case so the backplate faces downward toward the base. Get a long screwdriver, ideally magnetized so that you get the tiny screws into place without losing them inside the case as we did. Once it's in place, you can start looking at how you're going to attach all of the case cables onto the board.

FOR THOSE WHO DARE

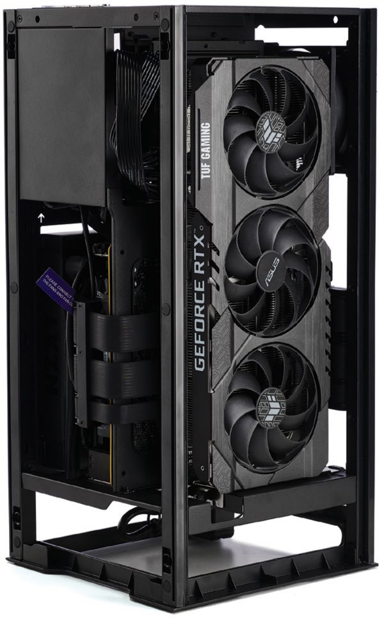
11 KEEPING COOL

TIME TO INSTALL NZXT's bundled cooler in the case. First, we opened the radiator door outwards and screwed it back into place. This was a little fiddly as the door needed to be held upright; we found it was easier with an extra set of hands to help. Then we took the LGA 1200 mounting bracket included in the NZXT box and installed it to the back of the motherboard—again, easier with an extra set of hands. Next, we took the label off the cooler, added more thermal paste to the thin layer which was pre-applied, and screwed it into the motherboard. The tricky part is when you swing the door shut because you need one person holding the cables out of the way so the door can close neatly over the motherboard. Again, this is the time to call for help if you have any.

NZXT
FOR THOSE WHO

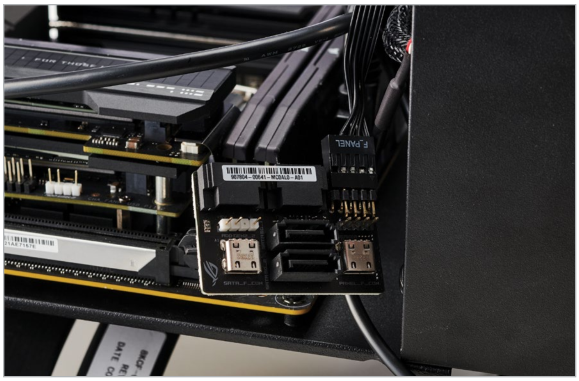
12 GRAPHICAL OVERLOAD

THAT'S THE HARD PART OVER. The next step is to install the graphics card on the other side of the motherboard, and with our triple-fan RTX 3070Ti, it's almost laughable how much of the case it takes up compared to the dinky motherboard. But we have to tip our hat to NZXT, it's an elegant solution and we're kind of impressed with how well it fits. There's even a little gap at the top of the case, which was unexpected. Again, the graphics card's sockets face downward in the case, with the internal PCIe slot and external screws holding the chunky unit tightly in place. The next task is to connect the power cables to the GPU and the GPU riser cable to the motherboard but, thankfully, that turns out to be pretty straightforward.



9 CABLE CONFUSION

AS WE WERE STUDYING the cables and the board itself, we came a little unstuck, as the F_PANEL connector wouldn't go anywhere on the board. We went to check the Asus box, and, sure enough, there was a small adaptor that added SATA ports to the motherboard, as well as the required header for the case's front panel. While we don't need the SATA ports on this build, as we're only using M.2 SSDs, this little adaptor is well designed and didn't impact upon the height of the motherboard in the case—if anything, the extra height made it easier to install the cable. As you start to add more and more cables to this board, it does get pretty tight for space, particularly on the headers sitting between the SSDs and the GPU riser cable.



10 HEADS AND TAILS

ATTACHING THE REST of the cables to the motherboard was quite simple, as there weren't that many of them, and the cables were all nice and short within the case. We also weren't doing anything with RGB or SATA drives in this build, which cut down on the number of cables and controllers required. While it's good to refer to the manual, it's hard to do anything wrong in this case just by matching the cables to where they fit on the motherboard, while NZXT's cable ties at the top of the case make it easy to keep everything neat and tidy. The only cable we didn't install at this stage was the GPU riser cable, as the GPU isn't yet in the case.

13 POWER AND GLORY

THE LAST STEP inside the case is to get that power supply back in and get all the power cables connected. Again, NZXT's excellent design makes this a fairly simple task, with modular cables needing to be connected for each of the motherboard, CPU, and GPU. We were a little too eager to remove the SATA power cables earlier in the build, because we then had to reconnect them as they're required to power the case's front panel. Again, all external cables run to the base of the H1 case, meaning the kettle lead goes in at the bottom, with a pre-installed internal power cable running neatly up inside the case and to the PSU.

14 CASING THE JOINT

WITH ALL OF THE INTERNAL components in place, it's time to put the case back together. The metal sides of the case slide neatly on in one U-shaped unit. Then you simply push the plastic back panel and the glass front panel easily into place, no tools required. System builders who like to show their inner workings might be disappointed by the opacity of the glass panel, which really is quite dark as you can see from our photos. Only the RGB ASUS TUF Gaming logo was visible inside, however, the packed-in nature of the motherboard, radiator, and fan means that there's not much to see in terms of the guts of the machine. It could also be argued that you don't really want a distracting light show in your living room anyway.

SOFA, SO GOOD

WE'VE BEEN eager to build inside the NZXT H1 v2 for quite some time now, and we weren't disappointed with the end result here. It's a stylish computer case that, while clearly inspired by the Xbox Series X, allows you to get the best of the PC into a living room-friendly box. It's a tight build for sure and there are times when it's useful to have another pair of hands available, but the short cable lengths and smart cable routing made things easier than we had initially feared.

In terms of the finished build, a number of things stand out. This is a computer that's easy enough to move from room to room, so it could be used as both an office and living room PC. One note of caution if you are thinking of doing this—the ports on the underside of the machine are fiddly to access, which could be a pain if you're disconnecting and connecting frequently. On the flip side though, it keeps everything nice and tidy and adds to the overall clean look of the case if it's on display.

In terms of setup, we had no trouble at all getting this PC up and running when it was completed. Asus's Armoury Crate software popped up as soon as Windows was installed, and allowed us to update everything on the system in one click, aside from the BIOS update, which we had to download to a USB and install manually. If possible, you'll want to connect the system to wired Ethernet, as no matter where you place the mobo's magnetic wireless aerial, it's going to ruin some of the minimalistic look of the case.

As mentioned in step 7, ultimately, we did have to go back in and swap the system drive and the gaming storage drive to improve performance on the primary SSD. Otherwise, the benchmark scores were all pretty much in line with our Zero Point machine, which features the same Samsung SSD and a similar RTX 3070Ti card.

There were some slight differences in gaming performance between our Asus card and the Zotac in the Zero Point system, but as all these differences were within a +/-6 percent range, that's negligible. What's notable is that includes the CPU-demanding *Total War* test, with our i5-12600K only just behind the more expensive Core i7-12700K. The Cinebench scores show that, for CPU-heavy workloads, the i7 does have a good lead-in multi-core performance, but that isn't too important for a gaming system. As you can tell from the benchmarks, this is a system on which you can comfortably play games at 1440p using Ultra settings. Plus, they looked great on our LG OLED test TV.

Aside from that, it's worth noting how well ventilated the H1 case is, and how (relatively) quiet the machine is under load. True, you will be able to hear this PC if it's right next to you, even under light workloads, but if it's in the corner of the room it won't disturb your gameplay. It's certainly a lot quieter than a PlayStation 4 console trying to keep *The Last of Us: Part II* going, that's for sure.

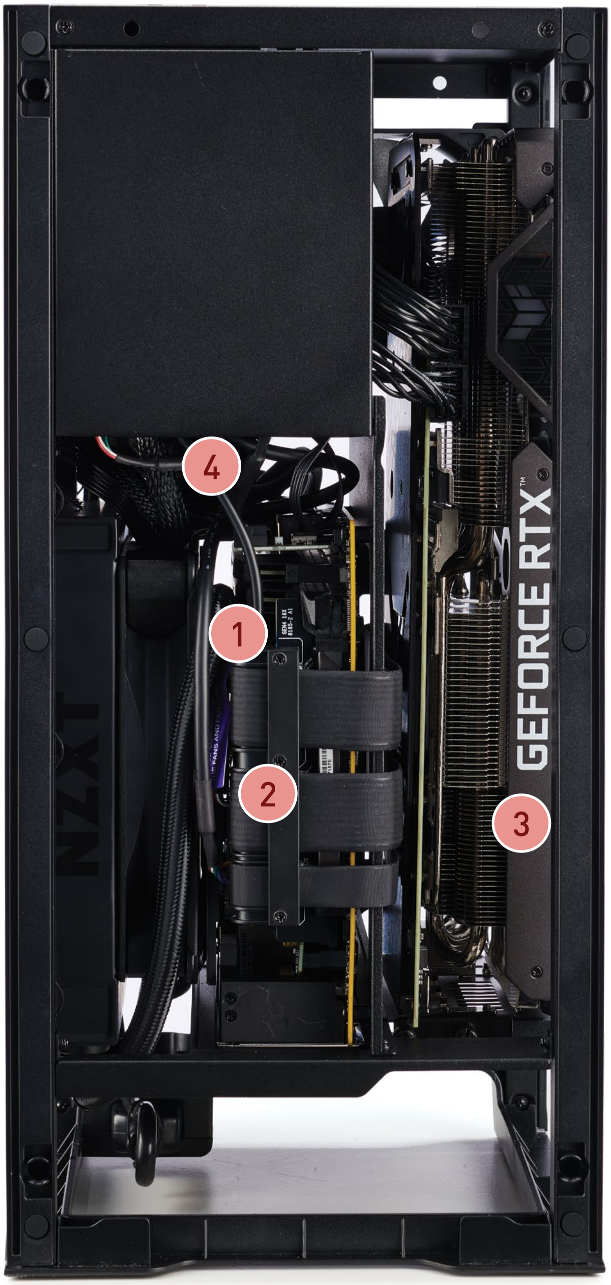
While the performance was excellent using our mid-to-high end components, we'd be slightly concerned about using more high-end components in this case, which is probably what a lot of people will want to do on a living room PC. Although 4K monitors still feel like a luxury in the office setting, we'd bet a much higher proportion of people have 4K televisions in their lounge. We'd love to whack an RTX 3090 in the H1, but the included power supply sadly wouldn't be able to cope, and that's even if we could fit the card in the case in the first place.

BENCHMARKS

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,931	1,770 (-8.3%)
Cinebench R23 Multi-Core (Index)	22,111	16,830 (-24%)
CrystalDisk QD32 Sequential Read (MB/s)	6,674	6,705 (0.5%)
CrystalDisk QD32 Sequential Write (MB/s)	4,920	4,925 (0.1%)
3DMark Fire Strike Extreme (Index)	17,991	16,943 (-5.8%)
Cyberpunk 2077 (fps)	64	61.33 (-4.2%)
Cyberpunk 2077 RTX (fps)	24	25.34 (5.6%)
Metro Exodus (fps)	74	74.31 (0.4%)
Metro Exodus RTX (fps)	53	53.34 (0.6%)
Total War: Three Kingdoms (fps)	78	74.8 (-4.1%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1440p zero-point consists of an Intel Core i7-12700K, a Zotac Gaming GeForce RTX 3070 Ti AMP Holo, an MSI MAG B660M Bazooka, 16GB of G.Skill TridentZ Neo DDR4-3600, and a 1TB Samsung 980 Pro. All games tested at 1440p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.



① With the motherboard, fan, and radiator stacked on top of each other, there really isn't much room inside the case when it's completed.

② The GPU riser cable really needs to be installed last, once the header cables are fitted and the graphics card is in place.

③ We were impressed with the amount of space for a large triple-fan graphics card, but check compatibility before buying a truly beefy GPU.

④ NZXT's cable management is excellent, but an extra pair of hands is useful to pull cables aside when installing the cooler.

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forums.pcgamer.com

PC GAMER

8 BEST
COUCH GAMING ACCESSORIES

XBOX WIRELESS CONTROLLER

The PC supports most controllers from Sony and Microsoft, plus the myriad PC options from Razer, SteelSeries, SCUF, and more. The Xbox Wireless Controller and PlayStation DualSense controller both connect to a PC over Bluetooth or USB. But, thanks to official integration with Windows and great force feedback in games, the Xbox Wireless Controller is where it's at. Turn the luxury up with Microsoft's Xbox Elite Wireless Controller Series 2 ($180), which has customization options and a carry case with a built-in USB-C charger. **www.xbox.com** • *RRP: $60*

XBOX WIRELESS ADAPTER FOR WINDOWS 10

Microsoft's official adapter has some nifty features. You can connect up to eight controllers on one dongle, wireless range is better than Bluetooth, and it provides stereo sound to your controller if you're plugging in headphones, although we recommend using a gaming headset. Pairing controllers is easy—press a button on the dongle, then the pairing button on the controller, and you're good to go. www.xbox.com • ***RRP: $35***

HYPERX CLOUD ALPHA WIRELESS GAMING HEADSET

This headset from HyperX is a godsend for living room PC gamers. It has a 300 hour battery life, which outlasts every other headset on the market. With over 12 days of battery life, this makes it ideal for forgetful gamers. Aside from that headline feature, it has a noise-cancelling microphone for crystal-clear chat, virtual surround sound so you can hear enemies around you, and earcup audio controls so you can tweak the audio without going into the Windows settings. www.hyperxgaming.com • ***RRP: $200***

HDMI 2.1 CABLE

To get the best out of your living room gaming PC, don't forget an HDMI 2.1 cable. Costing around $10 for a 3ft cable, they allow your graphics card to output 8K at 60Hz or a more feasible 4K at 120Hz. Compatible TVs from the likes of LG and Samsung will also be able to accept adaptive sync signals, such as Nvidia's GSYNC, resulting in visuals that will make your console-owning friends green with envy. **www.amazon.com** • *RRP: $11*

CORSAIR K63 WIRELESS GAMING KEYBOARD

We chose the K63 thanks to the fact it pairs with Corsair's Lapboard (see below for info). The K63 is wireless, using Bluetooth or the included USB dongle for lower latency, it features Cherry MX Red switches and lots of customizable lighting options. It has dedicated media keys, ideal for playing music when working. It also comes bundled with a wrist rest, and can be wired in at your desk.
www.corsair.com • *RRP: $110*

© CORSAIR

CORSAIR K63 WIRELESS GAMING LAPBOARD

We don't recommend playing games with a keyboard and mouse on your lap, but Corsair's lapboard is designed for the K63 keyboard (above) to slot and lock into, while a replaceable cloth surface on the right allows you to use a wireless mouse. The lapboard also includes a built-in wrist rest and a memory foam cushion underneath to ease the stress on your thighs. Corsair calls the lapboard "lightweight", although, at 1.85kg, that's pushing it. That said, it's a good way to play games in the living room.
www.corsair.com • ***RRP: $60***

HYPERX PULSEFIRE HASTE WIRELESS

This wireless mouse boasts a battery life of 100 hours, meaning you can use it for days without recharging. The wireless functionality only adds a couple of grams to the overall weight of the mouse over its wired counterpart, but you can use a USB cable for a latency-free experience. The dustproof switches are good for 80 million clicks, while the included grip tape can be used for comfort on the sides and on the buttons.
www.hyperxgaming.com • *RRP: $60*

RAZER LEVIATHAN V2

Razer's new soundbar improves on the original with better audio fidelity and more bass. The sound quality is impressive and, as you'd expect from Razer, it's packed with RGB lighting. The soundbar has some impressive spatial audio too, which is perfect for immersive games like *Resident Evil Village*. It also has Bluetooth support for when you want to play tunes from your mobile without having to boot your PC.
www.razer.com • ***RRP: $249***

© ELECTRONIC ARTS

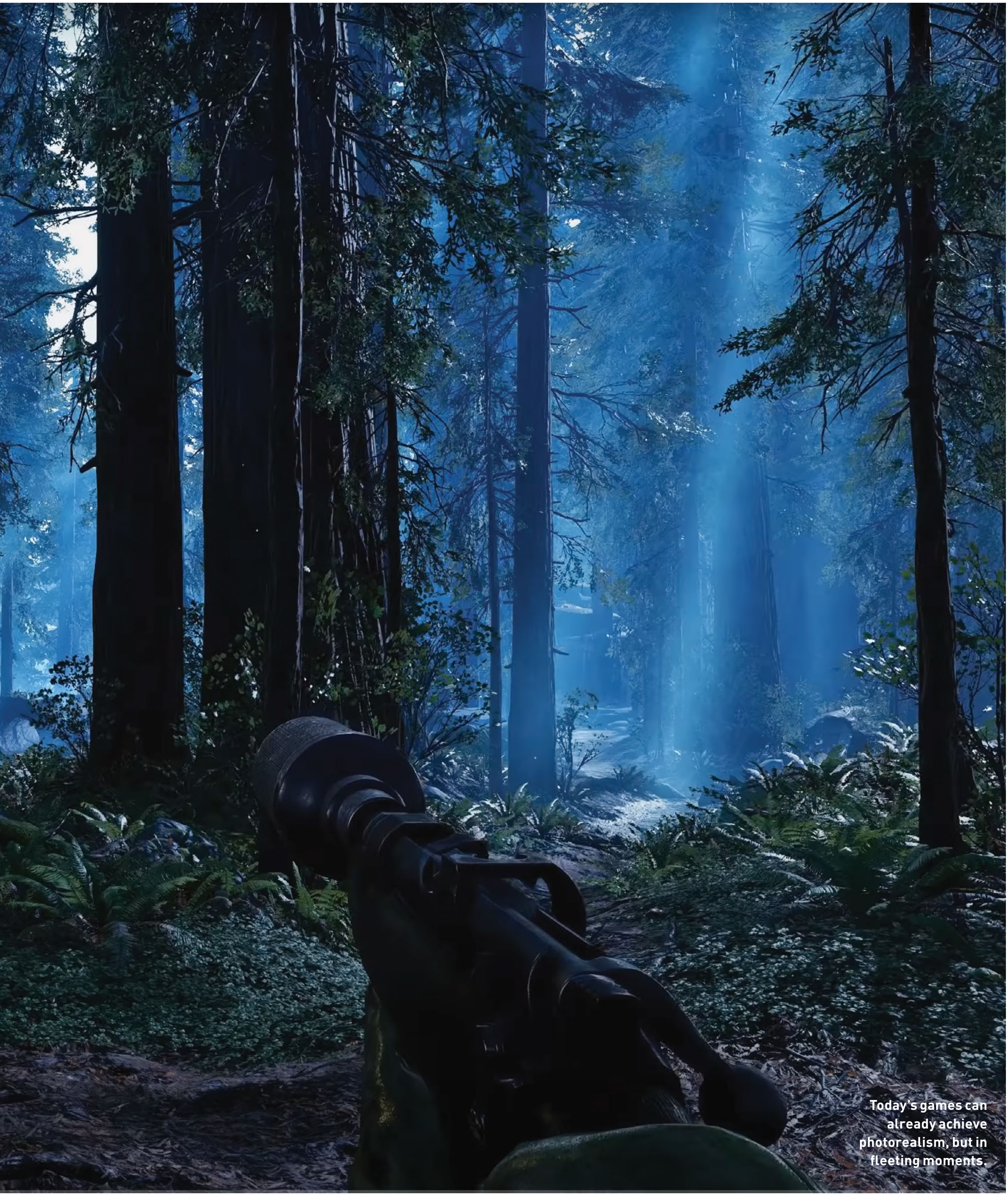
PHOTOREALITY CHECK

Real-time photorealism is the holy grail of gaming. And it's coming to the PC sooner than you think, says *Jeremy Laird*

FROM THE VERY DAWN of computer graphics, there has been one overarching goal. An end game for PC gaming, a final destination. We're talking of course about real-time photorealism. In experiential terms, graphics rendered in real-time that are indistinguishable from reality, at least as shown on a 2D screen. Achieve this goal and the observer will not be able to pick rendered computer graphics from real-life motion video. Of course, deciding when any given example of computer-generated graphics has achieved photorealism is always going to be a subjective call. We can all surely agree that the best CGI in movies and TV achieves that at least some of the time. But has any PC or console game yet achieved even fleeting photorealism? That's debatable.

Just occasionally, you get a snippet of gaming, maybe something with an ultra-high detail texture pack installed, that momentarily breaches the photorealism barrier. If you've seen the *Star Wars: Battlefront* Real Life Mod in action you'll know what we're talking about. Occasionally, just for a moment, it can look photorealistic.

But here's the thing. As you read these words, the PC graphics industry is taking what promises to be the last few steps towards what you might call sustained photorealism. Not photorealism all the time in every game. But sustained passages in certain games that can deliver what almost everyone would agree is photorealism. A huge array of technologies encompassing both hardware and software are currently aligning towards that end result. So get ready. Photorealism is coming to the PC, and sooner than you think.



Today's games can already achieve photorealism, but in fleeting moments.

Pre-rendered or in-game? Can you tell?

ONE WORD. PERFORMANCE. Ultimately, that's what stands between gamers and truly photorealistic graphics. Since the first computers capable of rendering pretty much any graphics at all, it has all been about performance. Any computer capable of processing general-purpose instructions can render a graphical scene of any complexity you throw at it. Even a full ray-traced 8K vista rendered on an old 286 CPU, all 33 million pixels in ultra-high photorealistic quality, is doable—the only question is how long it takes to get the job done. It might take a few months to spit out a single frame but it's still doing it.

Of course, exactly how long is acceptable for real-time gaming is what matters here. These days, most gamers don't get out of bed for less than 60 frames per second. That means the full game scene is rendered and outputted to the display 60 times each second. Maybe you can live with lower frame rates. Maybe you prefer higher. But something in the region of 60fps is a decent rule of thumb.

If a single frame takes a second, a minute, maybe even an hour to render, it doesn't matter how good it looks—you're not going to be gaming. Performance is everything and the solution to that problem is twofold. Either add more performance in hardware. Or make a given rendering task easier and faster.

This brings us neatly to perhaps the most superficially straightforward way to improve performance and achieve that photorealistic end game, namely upscaling. There's nothing new about the basic principle of taking a low-resolution image and mapping it to a larger resolution. It's just that, historically, the results have been less than impressive.

That's especially true in the digital era, where flat panel displays are unforgiving of generic spatial upscaling algorithms that average out data from a single pixel in a source image over several pixels in an upscaled one. The results in terms of image quality are typically soft and blurry, but from a performance perspective, the boost from upscaling can be huge.

To take an example, upscaling from 1080p to 4K is a quadrupling of pixel count. Using old-fashioned spatial upscaling approaches that have the advantage of adding little to no additional time to the image output process, that means a quarter of the rendering work for the GPU compared with native 4K rendering and far higher frame rates.

But what if you could have most of the performance benefits of upscaling while retaining the image quality of native rendering? Now that would be something. In theory, that promises a multi-generational performance boost in hardware terms. After all, from one GPU generation to the next, you're usually lucky to get 50 percent more performance, let alone actual multiples. Moreover, with GPU family life cycles typically lasting for around two years, an effective upscaling technology could power GPUs through the photorealistic barrier five or six years earlier than might otherwise be the case.

Enter an approach known as temporal upscaling. Unlike spatial upscaling, it isn't limited to using data only from the existing frame. Instead, multiple frames leading up to the new frame can be sampled, combining image data with vector or movement data to generate more detail.

Red Dead Redemption 2 is a great looking game, but isn't quite photorealistic.

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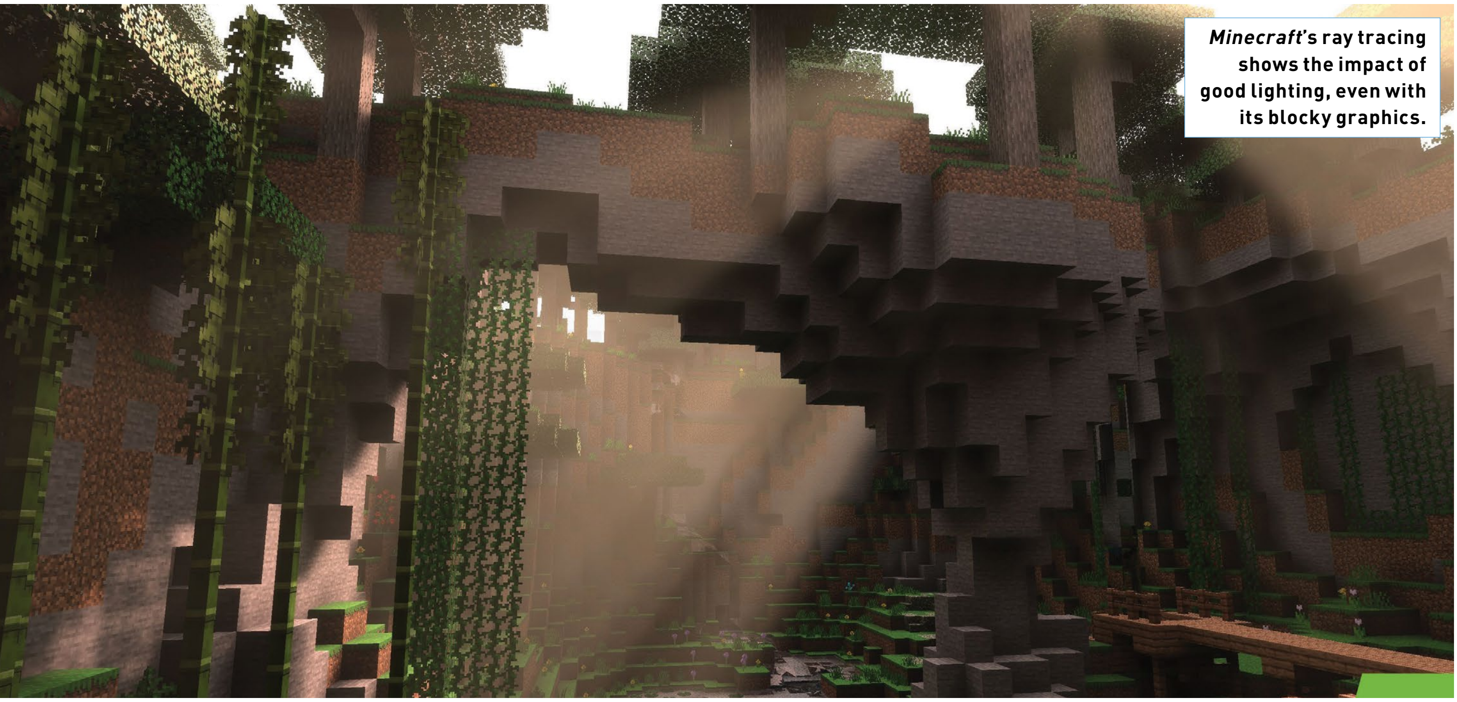
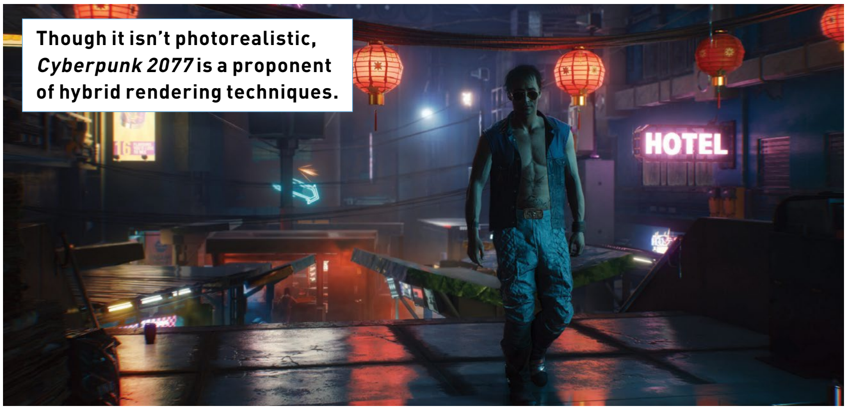


***Minecraft*'s ray tracing shows the impact of good lighting, even with its blocky graphics.**

Arguably, we have Nvidia to thank for this particular innovation, at least in terms of its real-world application to gaming courtesy of its Deep Learning Super Sampling (DLSS) technology. Without DLSS, we wouldn't be talking about temporal upscaling right now. From the beginning, Nvidia has pitched DLSS as a machine-learning technology that relies on the AI-accelerating Tensor cores in its modern RTX graphics cards. But DLSS only made an impact in its second iteration with an upgrade to temporal scaling.

To give DLSS its due, it does a lot of clever things. It takes the raw low-resolution input image and uses those motion vectors along with depth buffers and exposure data and pushes it all through algorithms honed by Nvidia's own industrial-scale neural networking compute infrastructure. But the most important element is the temporal rather than spatial approach to scaling. Indeed, what's clever is that temporal upscaling can result in image quality that is, at least in part, better than native image quality. That's because the motion data can be used to extract detail that isn't fully resolved, even at native resolution.

Where the AI and deep learning elements most likely add value to Nvidia's DLSS is in cleaning up the image artifacts that can arise from temporal upscaling, such as smearing and ghosting with moving objects and fizzing or jittering pixels in finer details. The only snag is that the second generation of AMD's competing FSR or Fidelity FX Super Resolution technology also made that jump from spatial to temporal upscaling. But AMD didn't make bold claims regarding the use of AI or machine learning and its scaling technology will run on any modern GPU, without so-called AI acceleration.



Though it isn't photorealistic, *Cyberpunk 2077* is a proponent of hybrid rendering techniques.

Instead, AMD is using hand-coded algorithms. AMD even pitched this difference as something of a differentiator between FSR and Nvidia's DLSS. "Broadly speaking, machine learning (ML) is an incredibly useful set of tools and techniques that can aid and accelerate this process. However, the results that ML achieves can sometimes not be the most optimal, lacking the spark of human imagination that can often lead to breakthroughs for complex problems," the company said in an official blog post.

One-zero to the humans over the machines? Maybe. For our money, we suspect the machine-learning element of DLSS is not all that significant. We also suspect, though this is rather more speculative, that DLSS could be made to run on any modern GPU without the need to use Nvidia's proprietary Tensor cores and give pretty much the same results.

However, in practice, it takes detailed analysis to differentiate FSR 2.0 from the latest version of DLSS in terms of visual quality. Both do a good job and it is their common use of temporal upscaling that is important, rather than any detail differences machine learning versus hand-coding may introduce. None of this is to denigrate Nvidia's contribution to the latest scaling tech. Nvidia might be over-egging the machine learning element to fit in with its broader marketing push around AI technology, but DLSS has still sparked a mini-revolution.

If that's the major generic performance-enhancing approach covered, next up is a

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Close, but not quite: on occasion, *Forza Horizon 4* comes pretty near to photorealism.

range of more specific image-enhancing technologies. One such group involves lighting, and arguably the daddy of that category is ray tracing. Although relatively new to the PC, ray tracing has been the basis of pre-rendered photorealistic graphics for film and TV for years. It just happens to be so computationally intensive that it hasn't previously been viable for real-time rendering.

The idea is simple enough, to simulate the way light behaves in the real world, the manner in which it reflects, refracts, scatters, and is absorbed. It's the gold standard for light modeling, but to generate realistic lighting requires a huge number of rays, each of which traces a complex path through a scene, bouncing off objects and experiencing various transformations. The results can often be spectacular. But even with the latest industrial hardware, producing Hollywood-quality results using pure ray-tracing to light a scene can, in extreme cases, still require hours per frame to render on a dedicated render server.

To solve that problem, Nvidia's RTX hardware ray-tracing technology, which first appeared in its Turing family of GeForce 2000 GPUs back in 2018, takes a range of approaches. Firstly, RTX drastically reduces the number of rays required to render a scene. The raw result is a noisy image with numerous gaps and empty patches. Nvidia then applies machine-learned algorithms to de-noise the image and compensate for the relatively limited number of rays in flight.

RTX also shifts some of the ray-tracing work onto dedicated RT cores. One example of these accelerated workloads is a computationally-intensive technique known as Bounding Volume Hierarchy (BVH). It's all about determining which triangles in the game scene a given ray will strike, a process that would previously have been calculated on the GPU's general-purpose shaders, dramatically reducing the overall frame rate. When Nvidia's RTX 2000 series of GPUs first arrived, a typical game scene with hardware-accelerated global illumination enabled by BVH calculations ran two to three times faster thanks to that new ray-tracing hardware.

While that sounds impressive, the reality was that enabling ray tracing still hobbled performance on those early RTX cards. And even then that was with limited rather than full-scene ray tracing. For the 'Ampere' RTX 3000 series of graphics cards, Nvidia boosted ray-tracing performance by another two times. We're expecting at least another doubling of performance when Nvidia's Lovelace RTX 4000 GPUs appear later this year, and quite possibly more. Two years further out when another new GPU architecture is introduced, you can expect at least yet another doubling.

Lighting engines such as Lumen in Unreal 5 are critical for realism.

Now, it's hard to say exactly how much more ray-tracing performance is needed to hit that real-time photorealistic target. But what we can say is that ray-tracing throughput is increasing at an exponential rate, one that comfortably outstrips ongoing improvements in conventional raster rendering performance. In short, with performance increasing two to three times each generation, it doesn't take many GPU life cycles before you have orders of magnitude more ray-tracing performance available.

That said, conventional ray tracing isn't the only way to achieve realistic lighting. One derivative of ray tracing, known as path tracing, is a kind of turbo-charged ray tracing that goes beyond tracking the path of a single ray of light as it bounces around the scene. Instead, it creates an even more realistic model of lighting that involves individual rays scattering or splintering into multiple rays depending on the simulated surfaces involved.

As that implies, path tracing is even more computationally intensive than standard ray tracing. Full-scene lighting via path tracing is not a remotely realistic proposition for real-time rendering on the

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NEXT-GEN GPUS

The future is photorealistic

It's arguably the worst kept secret in human history. Both Nvidia and AMD are tooling up to launch major new graphics architectures later this year. Throw Intel into the mix, with its first true attempt at gaming graphics, known as Arc, also imminent. If we're not expecting much from Intel Arc, the rumors around AMD and Nvidia's new GPU tech, codenamed RDNA 3 and Lovelace respectively, have been nothing short of spectacular.

Take RDNA 3. AMD's current top GPU, the Radeon RX 6950 XT, packs 5,120 shaders running at a maximum boost clock of 2,310MHz. All told, the 6950 XT is good for 21.5 TFLOPS of pure computational power. It's a beast. But early rumors around its replacement involved around three times the shader count, plus significantly higher clock speeds, thanks to a shift in manufacturing from TSMC's 7nm node to its more advanced 5nm tech.

As if that wasn't enough, AMD was rumored to have delivered an even bigger boost to RDNA 3's ray-tracing performance over RDNA 2. However epic those shader counts look, the ray-tracing uplift was going to be even more epic. Admittedly, core counts and clock speeds do not map one-to-one with actual in-game frame rates. But talk of a real-world performance boost as much as three times the existing RDNA family of Radeon RX 6000 GPUs was a thing.

More recently, those RDNA 3 numbers have been revised down. The latest rumors involve 12,288 shaders for the top Navi 31 GPU in the RDNA lineup, likely to be sold as the Radeon RX 7900 XT. However, factor in almost certainly higher clock speeds and you still have a truly massive uplift in performance.

Three times the frame rates of a 6950 XT? Probably not. But double the frame rate looks plausible. Add in the uplift from FSR 2.0 and you could be looking at three to four times the frame rate at 4K from a 7900 XT with FSR enabled than a 6950 XT at 4K without FSR. That is one hell of a generational leap forward.

As for Nvidia's upcoming Lovelace GPUs, also due later this year, it's a similar story. Nvidia chips will be getting a particularly big boost courtesy of a move from Samsung's generally unfavoured 8nm process to TSMC's fancy 5nm node. AMD was already using TSMC for its GPUs, so the step from TSMC 7nm to TSMC 5nm won't offer quite the same step.

Like RDNA 3, rumors around Nvidia's Lovelace have gradually adjusted from likely over-the-top claims of 2.5x performance boosts over the existing Ampere generation of RTX 3000 series boards to more realistic expectations of around 1.8x to 2.0x.

Of course, that's what is predicted for the higher-end members of the Lovelace range. Lower down the range, including boards like the RTX 4070 and 4060, the gains look less spectacular. The latest rumors have the 4060 delivering a roughly 30 percent increase in shader count over the 3060. Factor in maybe another 30 percent thanks to clock speed and that adds up to 60 percent in total. Healthy, generation over generation, but not the stuff of instant real-time photorealism.

© NVIDIA

PC. The solution to that insurmountable performance challenge for the PC, and indeed for making ray tracing more useful in general, is what is known as hybrid rendering. And that comes down to a deft balance between ray-tracing derived lighting and old-fashioned rasterization.

Rasterization, of course, has been the basis of most 3D graphics on the PC for decades. With rasterization, objects are generated from a mesh of virtual polygons, which are in turn converted into the pixels or visible dots on a PC's display. Each pixel is assigned an initial color value from the data stored in the polygon vertices. Further pixel processing or 'shading' can be applied, including changing pixel color based on general rather than ray-traced lighting models and applying textures.

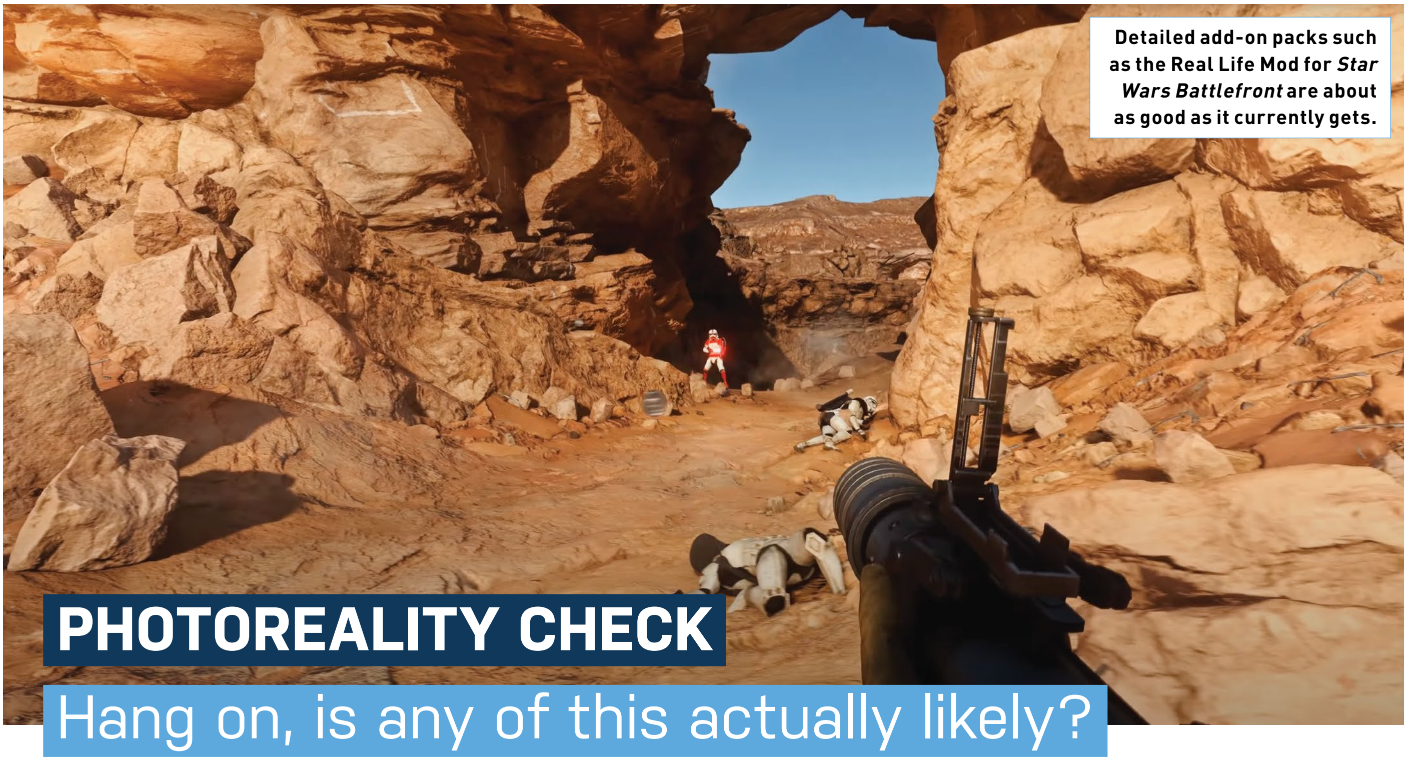
Rasterization has the advantage of being fast. But it's neither terribly accurate nor truly dynamic when it comes to lighting. The idea behind hybrid rendering is to take a rasterized scene and boost lighting quality via limited but targeted use of ray-tracing. There are various elements of a scene that might particularly benefit from a ray-traced rather than rasterized approach, such as casting shadows or reflections. The trick is to use ray-tracing only when it makes a big difference to realism while sticking with speedier raster rendering for everything else.

While lighting techniques are absolutely critical, they are not the only important factor when it comes to achieving photorealism. If you've ever played *Minecraft* running with ray-tracing enabled, for instance, you'll appreciate just how atmospheric and convincing the lighting can be. But you'll also know that the blocky architecture of a typical Minecraft level would never fool anyone into thinking that they were looking at a real-world scene. What you need to go along with the realistic lighting is geometric detail. And a heck of a lot of it.

Once again, the pre-rendered Hollywood-style example is useful. Generating sufficient geometric complexity for photorealism is doable for movie production, where it's tolerable for frame-time rendering to be measured in hours or even days. However, import movie assets, each with millions of polygons, into a game engine and you soon have a scene measured in billions of polygons and absolutely no chance of playable frame rates.

Existing game engines attempt to solve the problem courtesy of multiple versions of the same asset or object. The idea is to swap these versions in and out as seamlessly as possible, depending on the distance of the object. If a character model or a tree or a car is a long way off in the distance, you don't need nearly as much geometric detail to achieve realism as you do at short range.

Up to a point, this works. But it creates its own problems, including the



Detailed add-on packs such as the Real Life Mod for *Star Wars Battlefront* are about as good as it currently gets.

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PHOTOREALITY CHECK

Hang on, is any of this actually likely?

Time for a reality check. For sure, PC graphics are entering a golden age of rapid improvement after a period of relative stagnation. But photorealism? Come on!

The main objection to our upbeat narrative this month is the reality that it takes an awfully long time for the latest hardware to become mainstream. Sure, there's a plausible scenario where high-end PCs are capable of photorealism in five or ten years. But that won't be the hardware game developers will be targeting.

Instead, by then, something more akin to today's high-end rigs will be the common denominator that developers will have in mind. And as impressive as today's best hardware is, it's not yet capable of real-time photorealism.

In short, it's no good spending millions of dollars developing games that will only run on a tiny fraction of existing PCs. But much of what makes for photorealism can be scaled up within a given game engine. An obvious example is texture detail. Sure, it may take many years before a low-end gaming card can handle photorealistic texture detail. But that doesn't stop developers from including high-detail texture packs for those with the right hardware.

A similar philosophy applies to lighting techniques such as ray tracing. It's exactly the kind of feature that can be toggled on and off according to hardware capabilities. As we've seen, the latest game engines, including Unreal 5, also make it easier to scale geometric detail.

All of which brings us back to that example of the *Star Wars: Battlefront* Real Life Mod. That's just a texture pack. Imagine turning on much more realistic lighting effects and cranking up the geometry. The result will be games that look pretty good on regular hardware, but just tip over into photorealism with the details ramped up when running on high-end hardware.

bandwidth and storage requirements of loading multiple versions of the same asset, not to mention the development cost of generating many more assets. The solution? For that, we need to introduce a game engine that might well turn out to be the first that routinely achieves photorealism. Give it up, if you will, for Unreal Engine 5 and its Nanite engine. In fact, Nanite is just one of a suite of technologies in Unreal 5 that look likely to revolutionize game graphics and could be vital in achieving photorealism.

Believe the hype and Nanite will enable almost "limitless" levels of in-game geometry. Creators of Unreal Engine 5, Epic, describe Nanite as a "virtualized geometry system" capable of pixel-level detail and multiple orders of magnitude more geometric detail in real-time than previously possible. But how does Nanite achieve that? It's complicated, as they say.

Part of the cleverness involves only doing rendering work on detail that can actually be seen. That means not rendering objects that are off-camera, obscured by something else, or even self-occluding. Another aspect involves the compression and fine-grained streaming of geometric detail using automated processes. If that sounds like digital double speak, the idea is to use a single, ultra-high detail model to sample geometric detail on the fly. There's no more swapping in and out multiple versions of the same model. A single movie-quality asset can be imported into the engine without cratering in-game frame rates. The upshot, according to Epic's CTO Kim Libreri, is that "Nanite means freedom for game developers, the freedom to import full movie quality assets. You don't have to worry about generating normal maps or low-resolution proxies."

Libreri's point about "normal maps' is also important. Normal maps and bump maps are shader-accelerated features used to simulate geometric detail where

Unreal Engine 5's Nanite technology promises to solve the geometry problem.

doing the job directly in geometry would have been too computationally expensive. Those maps are processed by the GPU's shaders. But any GPU only has a given amount of shader horsepower to be shared across the entire rendering load. If geometry no longer has to be simulated by the shaders via bumps maps and normal maps, those thousands of tiny shaders in a modern GPU are free to apply their pixel processing magic to other elements of the scene, pushing the overall end result a little bit closer to photorealism.

It's also worth remembering that anything that makes life easier for developers to produce games will also get us to photorealism more quickly. Not only is sufficient rendering power required to achieve photorealism, but that improved hardware needs something to render. Being able to use existing libraries of high-quality assets without the need to manually create multiple versions or spend time hand-tuning each scene to make sure that polygon counts aren't crushing frame rates will make it possible for even smaller developers to aspire to photorealistic games.

That's pretty exciting. After all, the more people are working towards a given goal, the more likely it is to happen. With tools like Nanite widely available, it won't necessarily be only the big boys with hundreds of millions of dollars to spend that can deliver the visual goods. It might just be a small indie game developer that achieves something special.

Unreal Engine 5 also has a high-specification lighting engine known as Lumen. It's a ray-tracing-based approach that offers many of the same features and capabilities as lighting technologies such as hybrid rendering. But Epic says it does so more efficiently and without the need for the expensive dedicated ray-tracing hardware seen in Nvidia and AMD's latest GPUs. Essentially, it only uses full ray and path-tracing techniques when that helps with realism. As with many elements of the Unreal 5 engine, it's exciting but as yet not entirely proven.

Another contributor to photorealism from the Unreal Engine 5 is the World Partition feature. It doesn't directly impact detailed image quality, but it makes realistic game worlds much easier to achieve, both in real-time on your PC and in terms of the work developers do.

World Partition's trick is to streamline and partly automate the work of dividing large game worlds into smaller, more manageable chunks. Most obviously, that helps with development. Staffers can then work on multiple areas of the game in parallel without immediately impacting each other. Previously, it was often the case that work had to be carefully scheduled, with game files locked out from other users while they waited for another developer to finish a task.

World Partition also means less work for the PC itself during gaming. By breaking the game world into smaller parts that can be loaded on-the-fly in real-time, there's literally less game that needs to be loaded into memory and processed at any one time. Think of it as enabling smaller chunks of high-detail game world to seamlessly stream as you play as opposed to loading up a big, low-detail lump occasionally punctuated by obvious level loading episodes.

Hopefully, this broad set of technologies will push the PC in the direction of real-time photorealism. Combine upscaling, ray-tracing, and hybrid rendering with near-infinite geometry, more efficient game world streaming, and much faster hardware and you'll have the makings of the photorealistic end game.

Inevitably, there's plenty more that we haven't mentioned. How about in-game physics and fluid dynamics or character AI? Those features aren't necessarily important to realism—many game scenes don't involve water simulation or other characters on the screen. But to sustain that sense of realism for more than brief moments, that stuff definitely matters.

In that sense, the journey to photorealism isn't going to involve a big bang moment, a point before which no game was photorealistic and after which photorealism is ubiquitous. But one day soon, photorealism will have genuinely, undeniably arrived on the PC. It won't be attempted in all games. It won't even be attained all the time in a single game. But photorealistic real-time gaming graphics will be something the PC can add to its list of technological achievements. ⏻

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AMD ZEN 4 UNWRAPPED

Welcome to the modern age

AMD'S ZEN ARCHITECTURE revitalized the CPU industry, bringing much-needed competition and higher core counts to consumers everywhere. It's hard to believe we languished on 4-core Intel CPUs as the top mainstream solution for a full decade, starting with the Core 2 Quad in early 2007 and lasting until the Core i7-8700K launched in late 2017. If you wanted more CPU cores, you had to move to the more expensive LGA2011 HEDT (high-end desktop) platform. AMD kicked that idea to the curb with its first Ryzen 7 CPUs, and we've been watching an arms race of escalating core counts and clock speeds ever since.

Round four of Zen is now getting prepped for launch. At Computex and its Financial Analyst Day, AMD spilled the beans on much of what we can expect with the upcoming Ryzen 7000-series CPUs and the Zen 4 architecture. It's more than just a minor architecture update. Zen 4 comes with a new socket, a PCI Express upgrade, DDR5 memory support, and more. AMD hasn't backed off, and it plans to make Zen 4 its most competitive solution ever, scaling from low-power laptops all the way to massive supercomputers.

Get your wallets ready for a major upgrade, as Zen 4 looks to be the most significant overhaul of the Ryzen family since its inception.

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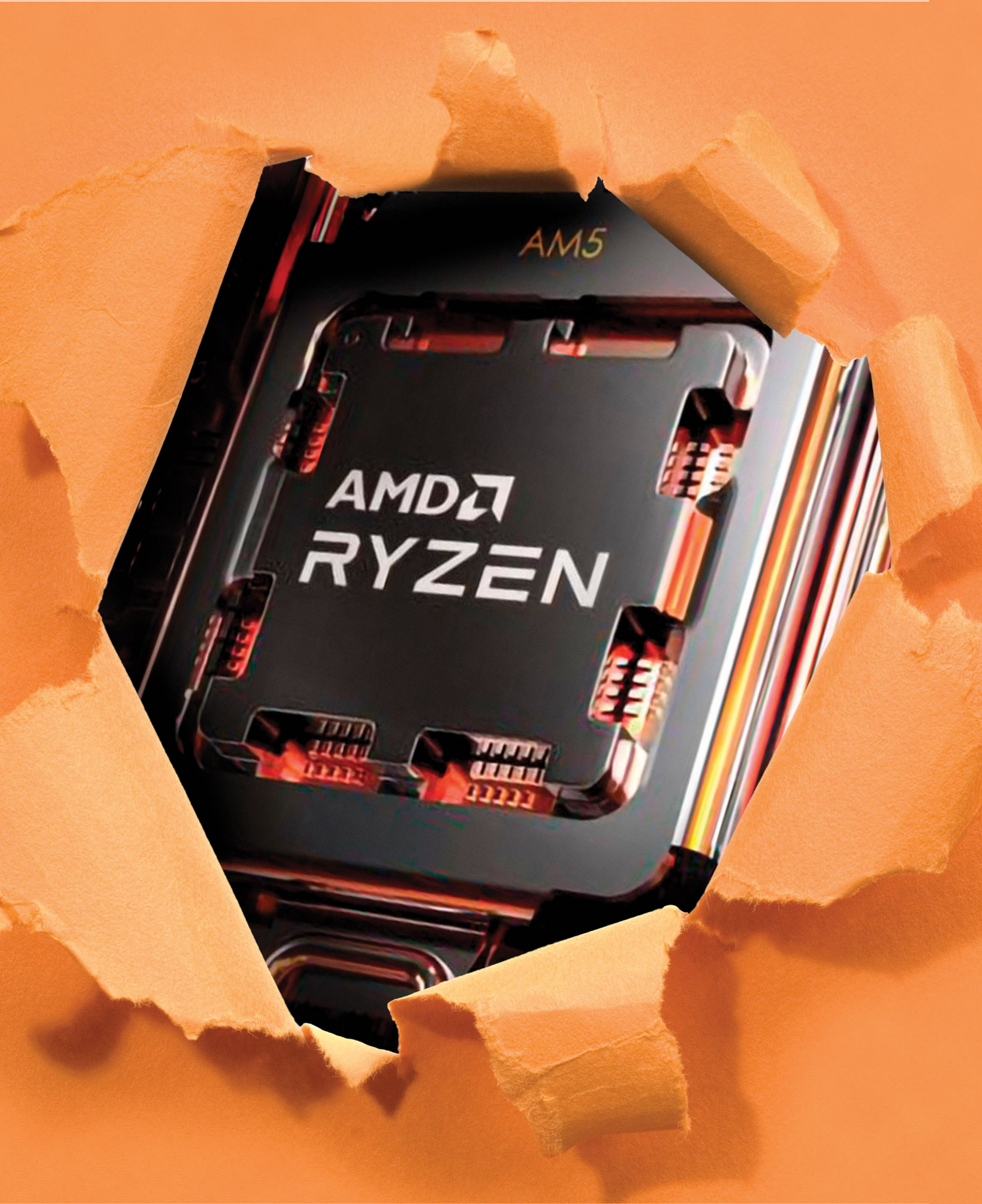
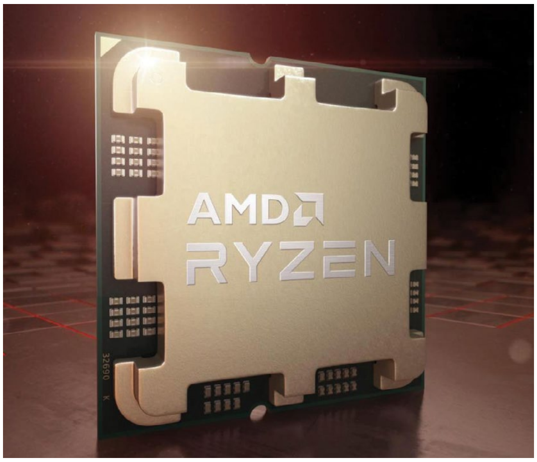

AM5
AMD
RYZEN

GUNNING FOR NUMBER ONE

AMD is ready to go after the performance crown once more with its latest Zen 4 family of processors. The Ryzen 9 5950X led in virtually every multi-threaded workload and put up some competitive numbers in gaming performance back in 2020. However, Intel reclaimed the overall lead with its 12th Gen Core Alder Lake processors and the Core i9-12900K in late 2021.

Prior to the 12900K, there were cases where Intel was still a little faster, such as in single-threaded workloads and some games, but Intel needed to get off its comparatively ancient 14nm process node and move into the modern era. Alder Lake did just that, using the rechristened Intel 7 process, then went a step further by including a hybrid architecture with performance cores and efficiency cores to attempt to deliver the best of all worlds.

AMD's Zen 4 architecture isn't quite as revolutionary as Alder Lake, sticking with a single all-purpose core architecture rather than taking a hybrid approach, but that's not a bad thing. Single-threaded performance still matters, and Zen 4 is targeting a greater than 15 percent improvement in single-threaded workloads. That's good to hear, as right now, if we look at single-threaded benchmarks, the Core i9-12900K beats the Ryzen 9 5950X by about 17 percent, depending on the application.



AMD's Zen 4 CPUs come with the new socket AM5, which ditches the pins and moves to a land grid array on the back.

What's more, AMD doesn't intend to give up any ground in the multi-threaded arena. The 5950X and 12900K currently trade blows in such workloads, ending in a virtual tie. Zen 4 aims to deliver up to 35 percent more performance, AMD says, which would easily put it back in top spot. It will get there through a combination of architectural enhancements, higher clock speeds, and increased power limits.

IPC AND CLOCK SPEED IMPROVEMENTS

One of the most impressive parts of the Zen 4 reveal at Computex is that AMD already had a chip running at 5.5GHz using a standard AIO liquid cooler. That wasn't in a heavily threaded benchmark, so the 5.5GHz was only on a single core, but that's still at least a 12 percent boost to CPU clocks compared with Zen 3 and the 5950X that topped out at

A FAREWELL TO SOCKET AM4?

With the forthcoming launch of Zen 4, it looks as though socket AM4 has finally reached the end of the line.

It has served us well, from the first Ryzen CPUs to the latest Ryzen 7 5800X3D, and, in many cases, all you need is a motherboard BIOS update to enable support for the latest Ryzen 5000-series processors on an old X370 or B350 motherboard.

With a move to DDR5 memory, however, AMD will be switching everything over to the new AM5 platform. Or will it?

AMD hasn't made any definitive statements on the matter, but one of the great benefits of the later Ryzen CPU designs is that they moved to a chiplet hierarchy, with an I/O die that handles the memory interface, PCI Express, and other core functionality linked up to one or more CPU chiplets that support anywhere from four to eight cores.

With Zen 4, there's a new I/O die that supports DDR5 and PCIe 5.0, linked once more to CPU chiplets via an updated Infinity Fabric. Here's where things get interesting.

DDR5 is and will remain a more expensive proposition than DDR4, as it requires on-DIMM voltage regulation, power management ICs, and an extra DRAM chip for ECC support. That will make it more difficult for AMD to sell budget-friendly Ryzen 7000 processors.

However, AMD could potentially use the existing Ryzen 5000-series I/O chiplet and link that up to new Zen 4 CPU chiplets, keeping the DDR4 and PCIe 4.0 support but also cutting costs. Such a design could theoretically drop into existing AM4 motherboards with a BIOS update.

Alternatively, AMD may simply keep making the current Ryzen 5000-series processor for socket AM4 to fill the budget role.

AMD Ryzen 5 5600X
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AMD's budget and midrange CPUs, such as the Ryzen 5 5600X, are still pretty fast and work in existing AM4 motherboards.

While the midrange and high-end CPUs will naturally transition to socket AM5, we wouldn't be surprised if AM4 solutions stick around for a few more years yet, targeting the budget market with 4-core through 8-core CPUs.

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4.9GHz. It's a sign that AMD already has silicon running at such clock speeds, and we expect to see lightly threaded workloads breaking the 5GHz barrier on many of the upcoming Ryzen 7000-series CPUs.

It's not just about faster clock speeds, however. IPC (instructions per cycle) improvements have been at the heart of AMD's Zen story, with Zen 3 boasting an impressive 19 percent increase in IPC compared to Zen 2—and Zen 2 in turn delivered an average 15 percent improvement in IPC compared with the original Zen architecture. IPC gains can come from a variety of sources, including larger caches, lower latency caches, deeper buffers, wider execution paths, and other architectural updates. AMD hasn't provided details on exactly where the improvement comes from with Zen 4, but it says it will deliver eight to ten percent higher IPC than Zen 3.

Taken together, a 12 percent boost to clock speed and a ten percent increase in IPC means AMD could see more like a 23 percent improvement in single-threaded performance. Either AMD is sandbagging with its stated goal of more than a 15 percent improvement or other factors are at play. However, at its Financial Analyst Day, AMD said Zen 4 should deliver an overall 35 percent improvement in performance. That announcement came several weeks after the initial claims of a 15 percent increase in single-threaded performance, so AMD may still be tweaking the BIOS and firmware.

Efficiency remains important as well. While socket AM5 increases the maximum power available to Ryzen processors quite a bit (see sidebar), AMD claims overall performance per watt has improved by 25 percent.

MEET THE AM5 PLATFORM

Socket AM4 has been with us for five years and three families of chipsets. Not every CPU during that time will work in every motherboard, however, mostly due to BIOS capacity constraints. The original 300-series parts originally didn't get Zen 2 and Zen 3 support, but AMD later provided firmware that would support those CPUs.

Meanwhile, the 500-series motherboards dropped Excavator from the supported CPUs list—many people forget that the first AM4 processors used AMD's last pre-Zen architecture—and support for the Zen and Zen+ families (Ryzen 1000- and 2000-series) remains hit and miss.

CPU support notwithstanding, the core socket has remained unchanged since 2017. In fact, the last major update to the AM4 platform came with Zen 2 and the 5000-series chipsets in 2019, which upgraded the interface to PCI Express 4.0. Zen 3 didn't need a new chipset, and AMD kindly didn't bother creating one, but we've now reached the end of the line. With socket AM5, AMD will switch exclusively to DDR5 memory,

A NEW DAWN FOR INTEGRATED GRAPHICS

AMD has had an on-off relationship with integrated graphics in the Ryzen era. The first-generation Ryzen processors were CPU-only, but then AMD created the 2400G and 2200G that ditched half of the CPU cores in favor of integrated Vega graphics. The other Ryzen 2000-series processors using the Zen+ architecture lacked integrated graphics, but the 3400G and 3200G added them in again.

That pattern continued up to the current Ryzen 5700G and 5600G that feature updated Vega 8 graphics. Ryzen 6000-series CPUs also have integrated graphics, but they're only for laptops.

While CPU-only solutions are sensible for enthusiasts who plan on installing a dedicated graphics card, business PCs and laptops use chips that offer integrated graphics—even if the PC has a dedicated GPU. They are slow graphics solutions, but for surfing the internet and basic office tasks they still suffice. Intel offers F-SKU processors that have the GPU portion fused off, but the chip still has those non-functional transistors. One potential benefit of Intel's approach is that you can still get by on integrated graphics while searching for a graphics card, which has been costly and time-consuming.

With Zen 4 and the Ryzen 7000-series, AMD seems to be taking the same path as Intel and will include RDNA 2 graphics in all the processors. There may be models that disable the GPU at some point, but OEMs like Acer, Dell, HP, and Lenovo will be pleased to have 'universal' integrated graphics for AMD's new AM5 platform. Even better is that AMD's RDNA 2 GPUs are capable, even in integrated form. The Steam Deck uses an 8-core GPU (eight compute units) to power its handheld gaming. We may see up to 12 CU solutions with Ryzen 7000.

The GPU will reside in the 6nm I/O die, giving it direct access to the DDR5 memory. DDR5 will also potentially double the memory bandwidth, which should be beneficial for built-in graphics.

It's still too early to say, but based on potential specs, the Ryzen 7000 graphics could be on a par with the dedicated Radeon RX 6400—not a powerhouse solution, but capable of handling 1080p gaming.

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Ryzen 7000 CPUs will have RDNA 2 integrated graphics, with a performance potentially similar to the Radeon RX 6400.

increase the number of CPU PCIe lanes, and upgrade the interface to PCIe 5.0. The Ryzen 7000-series will also come with integrated graphics (see sidebar). Not surprisingly, that means a complete overhaul of the platform and socket.

AMD will take this opportunity to finally ditch the pin grid array (PGA) interface of socket AM4 and will use a land grid array (LGA). Intel made that switch for its processors way back in the LGA775 era, when we were still using Pentium 4 processors, and never looked back. AMD stuck with PGA on AM2 through AM4, as well as FM1 through FM2+, though it did move to LGA with Threadripper.

With the increase in pin counts for socket AM5, PGA will finally go away—meaning no more bent pins if you happen to accidentally drop your CPU while trying to install it. Although conversely, the tighter packed pins within the motherboard socket can still be bent and are much harder to straighten.

AM5 will use LGA1718, which ends up with a similar pin count to Intel's LGA1700. That's not surprising, as the CPUs have similar feature sets. Both essentially have 28 total lanes of connectivity, though they are partitioned slightly differently. AMD uses a four-lane PCIe link to the chipset and provides an additional 24 PCI Express lanes for graphics and storage, whereas Intel uses eight DMI 4.0 lanes to link to the chipset and then offers 20 PCIe lanes for storage and graphics.

Both AMD and Intel have dual-channel memory support, and the remaining pins are for power and ground. The sockets look quite different, however, as Intel has a rectangular section on the bottom of its CPUs with a bunch of small capacitors, while AMD puts those on the flip side of the chip with cutouts into the heatsink.

As we've reported previously, AMD will require DDR5 memory with Zen 4 and socket AM5. Intel chose to include both DDR4 and DDR5 support with Alder Lake, a decision that ultimately helped a lot with adoption rates. However, there's still a chance that AMD will continue to support socket AM4 (see sidebar below). One way of looking at this situation is that AM4 requires DDR4 memory, and AM5 requires DDR5 memory, and never the twain shall meet.

Finally, Zen 4 will support PCI Express 5.0, though the actual speeds offered will depend on the chipset and motherboard. PCIe 5.0 requires tighter tolerances, and this results in more expensive motherboards, so there will be budget-oriented PCIe 4.0-only motherboards. As for the AM5 chipsets, things have also changed quite significantly from the previous AMD solutions.

CHIPSET CHIPLETS

AMD revealed that it will have three chipsets for socket AM5: B650, X670, and X670E. Except that it will also only have one chipset. The

MOAR POWAAAA!

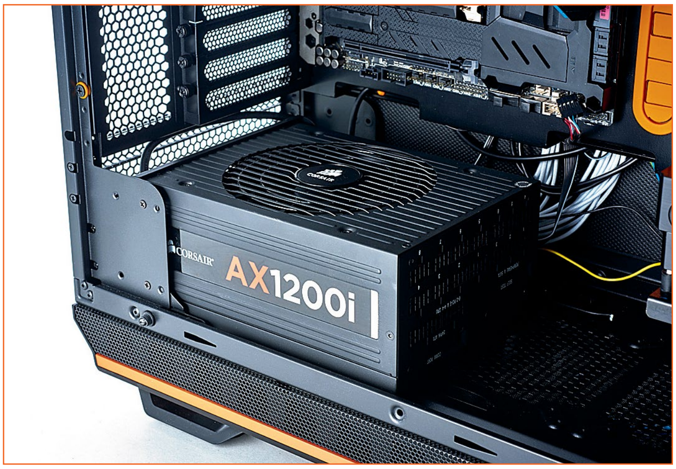
We've talked about the slowing down of Moore's Law many times in the pages of *Maximum PC*, and one of the key areas of impact is power requirements.

Even though Zen 4 will move to a 5nm process, gains in clock speed and performance mean that it will potentially use more power than AMD's existing solutions.

Socket AM4 had a TDP (thermal design power) rating of 105W, with a Package Power Tracking (PPT) limit of 142W—1.35x the TDP. With socket AM5, AMD has increased the TDP to 170W, with a 230W PPT.

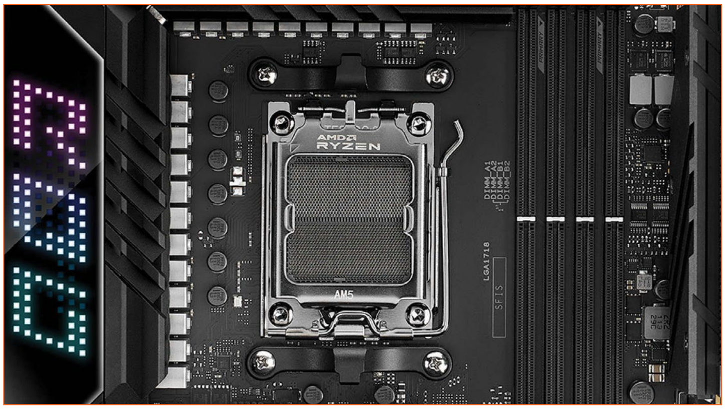
PPT is effectively peak power, the maximum the CPU can draw under short-term boost conditions. The situation is similar with Intel's more recent processors, where the Core i9-12900K has a base power of 125W but a maximum turbo power of 241W.

We've also talked about the efficiency of AMD's Zen 3 CPUs, and it's one of the areas where AMD still holds a lead over Intel's top Alder Lake CPUs. With Zen 4, however, AMD appears willing to give up on some of that efficiency advantage in pursuit of more performance.



With next generation graphics cards and CPUs set to push power use to new highs, 1200W PSUs may not be quite so overkill later this year.

We don't have the full set of details for the upcoming Ryzen 7000-series CPUs, and it's a safe bet there will be plenty of options that won't come anywhere near the 170W TDP limit. The top solution that will ultimately replace the Ryzen 9 5950X on the other hand will use every bit of that increased power limit. We've seen with the current Zen 3 chips like the 5950X that performance ultimately ends up being limited by power rather than thermals, so it makes sense for AMD to provide more headroom with its next-generation socket. After all, if AM5 proves to be anything like AM4, it could be with us for many years to come.



The new socket AM5 will have 1718 pins on the motherboard side, similar to what we've seen with Intel's LGA sockets.

primary chipset design has an x4 uplink and two x4 downlinks, with the uplink normally connecting to the CPU. However, a second chipset can be used on a motherboard, linking to one of the x4 downlinks of the first chipset. This allows AMD to offer a range of connectivity options through different chipset names, all while focusing on manufacturing a single chip to optimize production and yields.

The B650 chipset will consist of a single chip on the motherboard. AMD hasn't specified the speed of the CPU to chipset connection, but we'd assume it's working to get PCIe 5.0 speeds to increase the bandwidth between the CPU and chipset(s)—this is one area where Intel's use of an eight-lane DMI connection looks superior, though AMD would get the same total bandwidth via a four-lane PCIe 5.0 link. B650 motherboards will allow for one M.2 PCIe 5.0 slot from the CPU, but the graphics lanes will be limited to PCIe 4.0 speeds.

For X670E, everything gets upgraded to PCIe 5.0. It can support two graphics cards (x8 connections) along with a direct M.2 PCIe 5.0 slot. X670E will target enthusiasts and overclocking and represents a step up from the existing high-end tier of AMD motherboards. X670 strikes for a middle ground. It still uses dual chipsets, but the graphics slot link to the CPU can be either PCIe 5.0 or 4.0, which will be up to the motherboard manufacturer. That means there will be high-end and midrange X670 boards.

The secondary chipset gets daisy-chained to the primary chipset, which could add a bit of latency, but for most devices that shouldn't matter much. Each chipset has four PCIe 3.0/SATA lanes (can be partitioned as 4+0/2+2/0+4), six USB 3.2 Gen 2 10Gbps ports (two can be fused into a single can be fused into

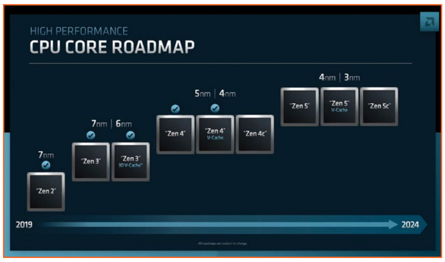
THE ROAD AHEAD

If Zen 4 sounds great, you'll be shocked to hear that AMD is already working on... [drumroll]... Zen 5! We do have to give credit to AMD for keeping things simple on the architecture naming, though of course, that doesn't account for the numerous codenames—Raphael, Granite Ridge, Phoenix Point, Strix Point, and plenty of other names are floating around. Slated for a 2024 release, Zen 5 will look to carry forward the Zen legacy. At this stage, AMD isn't providing much information on performance or new capabilities that it's planning for Zen 5, but it has shared a few other details.

For example, there will be V-Cache versions, such as the Ryzen 7 5800X3D and the Milan-X server CPUs, of Zen 4 and Zen 5 processors. AMD hasn't committed to any particular set of SKUs, stating only that it will make V-Cache chips "where it makes sense." We expect there will be at least one V-Cache Ryzen 7000 chip targeting higher gaming performance, and given the cost of such an endeavor, we wouldn't expect such a solution outside of the high-end and enthusiast markets. Servers, on the other hand, will likely see multiple V-Cache options.

The Zen 4c and 5c also warrant a mention. Those are cloud-optimized solutions focusing on increased core and compute density. Where the 'Genoa' server solutions feature up to 96 cores, 'Bergamo' cuts some functions and will deliver up to 128 cores.

Both will be manufactured using the same TSMC 5nm process, but Bergamo will likely reduce or eliminate the shared L3 cache. AMD will have similar options with Zen 5 and 5c, built on either 4nm or 3nm nodes in the future.



AMD's CPU roadmap now has Zen 5 due for a 2024 release, along with a few other options.

Another roadmap shows AMD's plans for the mobile market. It recently launched the Ryzen 6000-series 'Rembrandt' processors featuring Zen 3+ architecture paired with RDNA 2 graphics, fabricated on a 6nm node.

The '+' in the Zen 3+ may refer to the updated memory interface, which now supports DDR5 and LPDDR5 for higher bandwidth. Next up will be 'Phoenix Point,' a 4nm design that pairs Zen 4 CPU cores with RDNA 3 graphics, along with AMD's AI Engine (AIE) that comes from the Xilinx acquisition.

That should arrive next year, then in 2024 AMD has plans for 'Strix Point', combining Zen 5 cores with an 'RDNA 3+' GPU and AIE, to be manufactured on a future 'advanced node'.

© INTEL, AMD

a single Gen 2x2 20Gbps port), six USB 2.0 ports, and two x4 PCIe 4.0 downlinks. B650, therefore, has up to 12 USB ports (half 2.0), two sets of x4 PCIe 4.0 connections, and four PCIe 3.0 lanes. X670 and X670E have up to 14 USB 3.2 10Gbps ports, three x4 PCIe 4.0 links, and eight PCIe 3.0 lanes.

The dual chipset approach has other benefits, beyond increasing the number of USB ports and PCIe lanes available. With the tighter signaling requirements of PCIe 4.0 and 5.0, many motherboards had to include a PCIe redriver to get the signal to the furthest PCIe slots. With X670, the second chipset can be moved midway between the distant PCIe slots and the primary chipset, functioning as both additional connectivity and a PCIe redriver.

GETTING READY FOR ZEN, ROUND 4

AMD's new Zen 4 CPUs and the accompanying motherboards are due to arrive this fall, promising improved performance,

Top-tier motherboards such as the Asus ROG Strix X670E will have dual chipsets and full PCIe 5.0 functionality for storage and graphics.

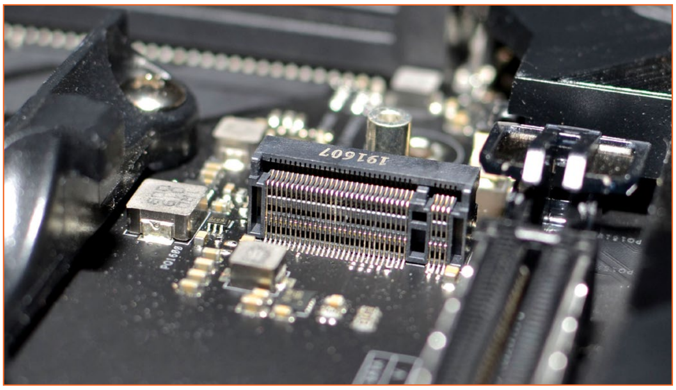
THE NEED FOR PCIE 5.0

One of the headline items for both Intel's Alder Lake and AMD's upcoming Zen 4 is support for PCI Express 5.0. Doubling the potential throughput for the various connected devices sounds like a good thing, but the need for PCIe 5.0 is a bit nebulous. There's a lack of consumer devices that support the standard, so it's more a case of 'build it and they will come'.

PCIe 5.0 requires tighter tolerances and shorter traces on motherboards to keep the signal clean. That means motherboards with multiple PCIe slots will need to add PCIe redrivers (or a second chipset) for the distant slots.

Power requirements are another concern, and one of the reasons many laptops still opt to use PCIe 3.0 connectivity. Still, for the desktop and server markets, having the option to upgrade to a PCIe 5.0 device in the future is good, and it also establishes a baseline of functionality for AMD's new platform.

AMD will offer PCIe 5.0 for the first M.2 slot on all of its Zen 4 motherboards, but the graphics card slots can opt for 4.0 or 5.0 speeds, depending on the chipset and motherboard design.



M.2 SSDs are one of the few devices that run into PCIe 4.0 speed limits.

Despite Intel's Z690 platform launching with PCIe 5.0 support in November, we're still waiting on the first Gen5 devices. We expect to see M.2 SSDs that support the new interface speed along with new graphics cards from both AMD and Nvidia with PCIe 5.0 support before the end of the year.

However, given the small difference in performance between PCIe 3.0 and 4.0 even with the fastest graphics cards like the RTX 3090 Ti, storage devices are more likely to demonstrate more of a benefit. If you're copying hundreds of gigabytes of data on your SSD, it's something to look forward to, but the real-world impact for most won't be felt for years to come.

© ASUS

connectivity, and features. As the first 5nm x86 processors to hit the market, AMD will once again hold an advantage over Intel, and it intends to close the performance gap in single-threaded workloads and regain the overall lead. We expect to see at least 16-core/32-thread Ryzen 7000-series processors, and with improvements in IPC, clock speeds, and a higher power limit, it's shaping up to be an epic battle between Zen 4 and Raptor Lake.

One of the benefits of AMD's current approach to processors is that it still uses a single type of CPU core. There will be no need for special scheduling updates to help operating systems know how to get the most out of Zen 4, which isn't the case with Alder Lake and the upcoming Raptor Lake. If you're still using Windows 10, Zen 4 should be as happy running the older OS as it is Windows 11, though Microsoft will eventually stop supporting Win10.

It will also be nice to get integrated graphics support on most if not all Ryzen 7000-series processors, and if history is any indication, we expect the RDNA 2 graphics to be significantly faster than the Xe solutions Intel continues to ship, particularly on desktops. Or maybe not—maybe it will only be laptops that get higher performance graphics, and desktops might get more limited solutions. We'll find out more in the coming months.

Overall performance is a function of IPC and clock speed, both of which are getting a boost in Zen 4.

AMD has been gaining ground on Intel in the CPU world over the past five years of Ryzen processors, and Zen 4 looks to be the most promising option so far. Zen 3 claimed the overall performance crown for a while, but Intel's CPUs still tended to be faster in games and single-threaded workloads. With continued improvements in IPC and clock speeds of 5.5GHz, AMD may take the crown in every discipline. We'll have to pay the piper his due, with complete motherboard, memory, and CPU upgrades to get the most out of Ryzen 7000 but, hopefully, the end result will be worth it.

TO AVX-512 OR NOT TO AVX-512

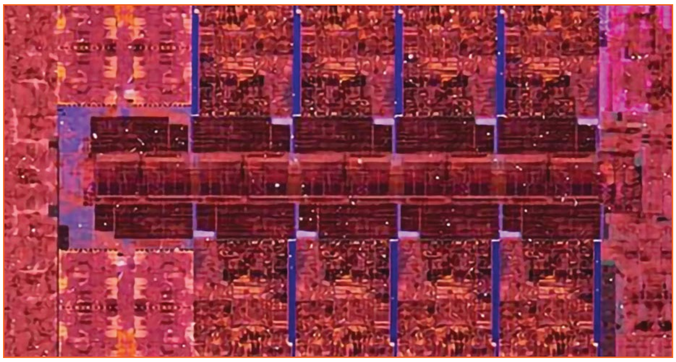
After pushing AVX-512 as a useful new instruction set for workloads with its Ice Lake, Tiger Lake, and Rocket Lake families of processors—as well as the HEDT Skylake-X and derivatives, not to mention the Cannon Lake SKU—Intel decided to disable AVX-512 support in Alder Lake.

The performance cores (P-cores) contain the necessary transistors and functionality, but the smaller efficiency cores (E-cores) do not, and Intel decided it was better to disable the instruction set rather than trying to have two CPU architectures active with different instruction sets.

AMD has no such issue, as all the Zen 4 cores in its upcoming CPUs are the same, and it has added AVX-512 support in the new architecture. This represents a reversal from Zen 3 and Rocket Lake, as AMD previously only supported AVX-256. That resulted in certain benchmarks and applications (eg. y-cruncher and Handbrake) favoring Intel CPUs, and the tables will now be turned.

AVX-512 isn't without controversy, and Linux creator Linus Torvalds has publicly shredded the instruction set, stating, "I hope AVX512 dies a painful death, and Intel starts fixing real problems instead of trying to create magic instructions to then create benchmarks they can look good on." AVX-512 use can also cause a CPU to draw far more power, so Intel has included an AVX offset where the maximum CPU clock speed while running AVX and AVX-512 instructions is lower than in other workloads.

Intel will still have AVX-512 support in its 'Sapphire Rapids' Xeon processors, as will AMD with its 'Genoa' EPYC chips based on Zen 4 architecture. But for consumers, Intel seems to be moving away from supporting the instruction set that it created.



The eight P-cores in Intel's Alder Lake all support AVX-512, but Intel opted to disable AVX-512 support due to the hybrid architecture.

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CENTERFOLD

PERFORMANCE GEAR LAID BARE

1 CONTROL

There are many ways to control the Ray, including touch-sensitive buttons on the top, voice control if you have a smart speaker or phone, the Sonos app, or by using Spotify or TIDAL Connect. You can also program most infrared television remotes if it's in the living room.

2 DESIGN

The Sonos Ray is available in both black and white colorways. The 22-inch width is compact for a Sonos soundbar and the tapered design gives it a unique flourish. A light at the front confirms your button presses, so you can see when the volume is being changed.

3 CONNECTIVITY

Sonos makes its products simple to use, meaning inputs on Ray are limited to optical, ethernet, and power. There's not much else you need, although you are losing HDMI ARC here. All the best parts of Sonos's ecosystem are present, meaning you can pair rear speakers and a sub for a 5.1 setup or add the soundbar to a multi-room system.

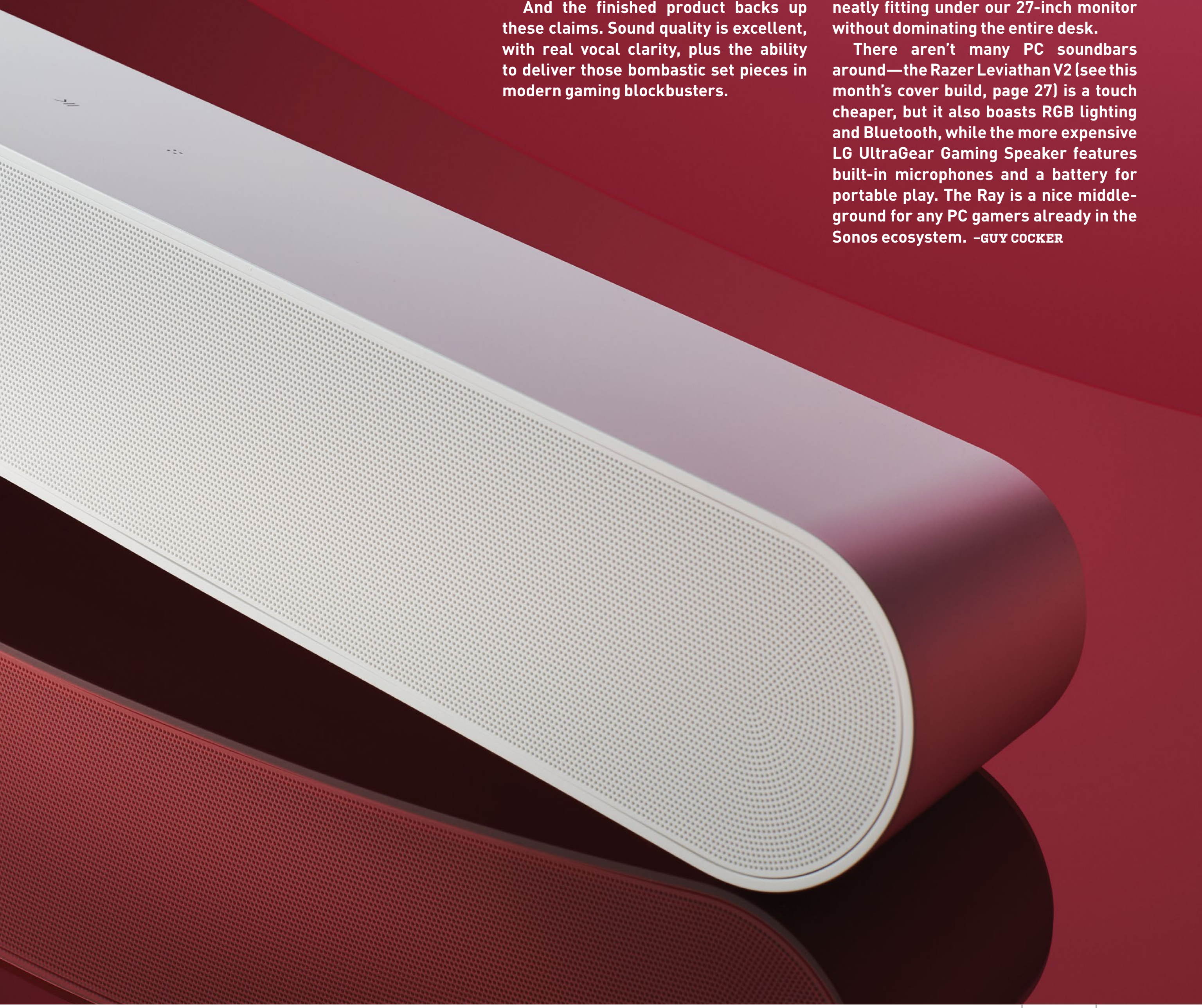
Sonos Ray

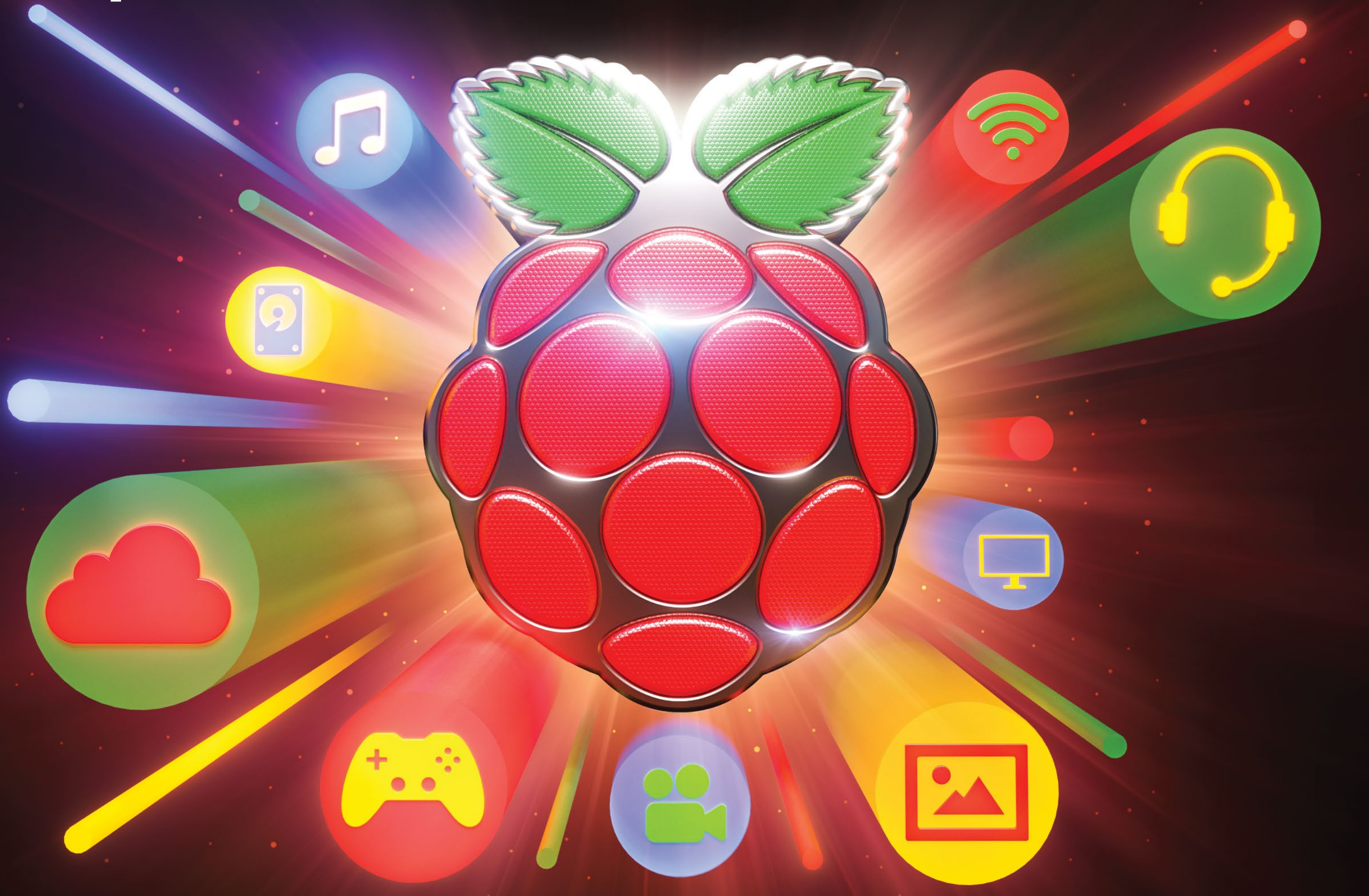
SONOS HAS been doing music streaming since before the iPhone, but the company is now targetting PC gamers with its Ray soundbar. This soundbar is still going to find its way into more living rooms than it will offices, but this is the first time Sonos has pitched a product directly at PC gamers, claiming that the Ray delivers a "next-level gaming setup".

And the finished product backs up these claims. Sound quality is excellent, with real vocal clarity, plus the ability to deliver those bombastic set pieces in modern gaming blockbusters.

The key difference between this and Sonos's more expensive Beam and Arc soundbars is that the Ray uses an optical audio connector rather than HDMI. That means you lose HDMI ARC control, but you gain the ability to connect to most gaming-oriented PC motherboards. It also helps that Ray is a more compact soundbar than Sonos's other offerings, neatly fitting under our 27-inch monitor without dominating the entire desk.

There aren't many PC soundbars around—the Razer Leviathan V2 (see this month's cover build, page 27) is a touch cheaper, but it also boasts RGB lighting and Bluetooth, while the more expensive LG UltraGear Gaming Speaker features built-in microphones and a battery for portable play. The Ray is a nice middle-ground for any PC gamers already in the Sonos ecosystem. **–GUY COCKER**





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BUILD A PI-POWERED MEDIA CENTER

Make your own home entertainment hub with a Raspberry Pi, free software, and a few programmable LEDs. *Jonni Bidwell* shows you how

EVER SINCE the dawn of Raspberry Pi computers, people have been making media centers out of them. Even the original Pi, thanks to its VideoCore SoC, was able to play 1080p content smoothly, 256MB of RAM notwithstanding. Media center distributions quickly sprang up to exploit this and using your Pi as a media center was quickly seen as an easy way to get into the world of micro PCs.

The first media player software to make it onto the Pi has its roots in the original Xbox console from the early 2000s. Apart from being a platform for playing Bungie's *Halo*, this console was popular with homebrew enthusiasts, since, thanks to easily exploited buffer overflows in popular titles, they could be made to run unofficial titles. One such title was the Xbox Media Player, which in 2008 became Xbox Media Center, underlining that it was more than just a player. This application found its way to the Pi by way of the RaspBMC distribution, put together by student Sam Nazarko and released not long after the Pi itself.

Today, thanks in part to legal threats from Microsoft, XBMC is known as Kodi. RaspBMC has a new name too—OSMC (Open Source Media Centre), reflecting the fact that builds are also available for Vero and first-generation Apple TV devices. Kodi can be installed on just about anything running Linux, and it works great as a desktop app (even on Mac and Windows), but if you're looking to make a dedicated media player out of it then it makes much more sense to deploy a tailor-made operating system.

OSMC is a great choice, but by far the most common Pi-based multimedia distro is LibreELEC, which we'll use here.

KODI ACADEMY

New versions of Kodi and LibreELEC are out, but only for recent Pi owners

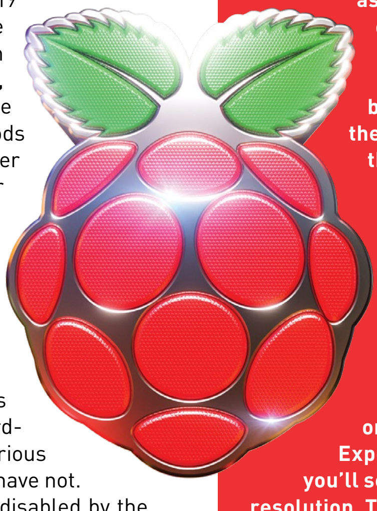
LIBREELEC was forked from OpenELEC, which began life in 2009 as a minimal Linux flavor for running XBMC. This also found its way to the Pi shortly after the latter's inception. In 2017, the project was abandoned and most of the developers joined the LibreELEC project. LibreELEC describes itself as Just Enough OS (JEOS) to run Kodi and strategically times its releases to coincide with those of the latter. Kodi 19, codenamed Matrix, was a big release and in August 2021 this was incorporated into LibreELEC 10.0.0. Since then, there have been a few point revisions of both. The current version is 10.0.2 with Kodi 19.4, but it's possible newer editions will be available by the time you read this.

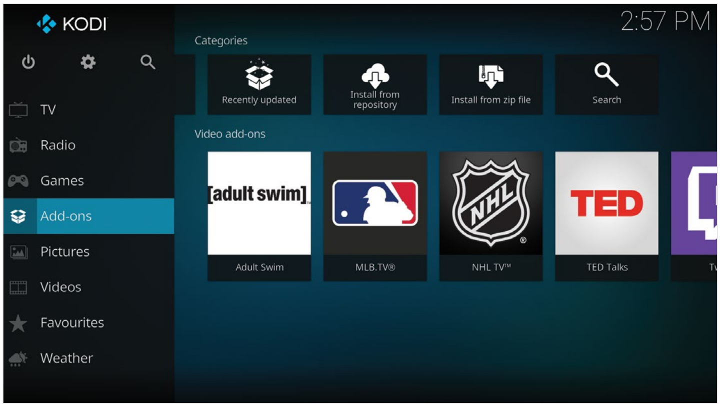
Breaking changes

Only recently has support for the older Pis, anything other than the Pi 2 and Pi 3, been added to LibreELEC—and the Pi Zero and original Pi won't be supported at all in any future release. If you have any trouble, you can happily run LibreELEC 9 on earlier versions of Pi, and the interface and functionality are much the same. In fact, we use this version for the last and most colorful part of this feature. See the boxout for more on LibreELEC 9.2 and Kodi Leia.

There are a few reasons for the high hardware bar, the most pressing being that Pi graphics drivers (and those of many other small ARM devices) in LibreELEC are undergoing a major rewrite. Previously, each build would incorporate the required vendor kernel, other proprietary weaponry, and some ugly patches to get accelerated graphics working with Kodi. This was an ad hoc process and since Kodi 19 no longer supports most of these proprietary methods, they have been removed in LibreELEC 10. Instead, the goal is for all platforms to use uniform display and decoding methods by way of the GBM (Generic Buffer Management) and V4L2 (Video for Linux 2) APIs. This will enable all builds to run on a mainline kernel without any ugly hacks.

Besides those changes, the plugin system has been upgraded to Python 3. This means that any addons still based on Python won't work. All of the official Kodi addons have been updated, but many third-party ones (including many nefarious ones used to access pirate content) have not. Python 2 addons are automatically disabled by the upgrade, so if you rely on any of these it's worth holding fire on LibreELEC 10 until they're updated. Fortunately, and big thanks to the Pi Foundation, we had in our possession an 8GB Pi 4, which we can confirm works beautifully with LibreELEC 10.





In no time, you'll be able to access your media, as well as stream it from proprietary services.

LIBREELEC 9

Usually, LibreELEC development focuses on the latest release, but last year saw a rare point release (9.2.8) to the previous edition. This happened due to changes in the Widevine DRM used by Netflix and many other streaming services, which all stopped working on LibreELEC 9 until the new library was properly accommodated.

We know that many of you won't have the latest Raspberry Pi models, which is why we've done our best to make sure our guide covers as many iterations as possible. The only major discrepancy we found is that Netflix (and possibly other Widevine-reliant services) fall back to software rendering with the new Widevine service. Because the add-on tricks Netflix into playing at 1080p (using the same trick as the popular browser plugin), this places pressure on the Pi's CPU, sometimes leading to stuttering and audiovisual desynchronization. For a smoother experience, limit Netflix's app playback to 720p by right-clicking the add-on and selecting Settings. In the Expert setting panel, scroll down and you'll see the option to limit the stream resolution. The Pi 4 has no problem decoding 1080p in software: the load average was barely above 1.0, as opposed to the Pi 3 where it was well above 3.5, and as such, close to CPU-saturation.

© KODI

SETTING UP KODI

LibreELEC is probably the easiest Linux distro you'll have ever installed, and Kodi will be ready for action in no time

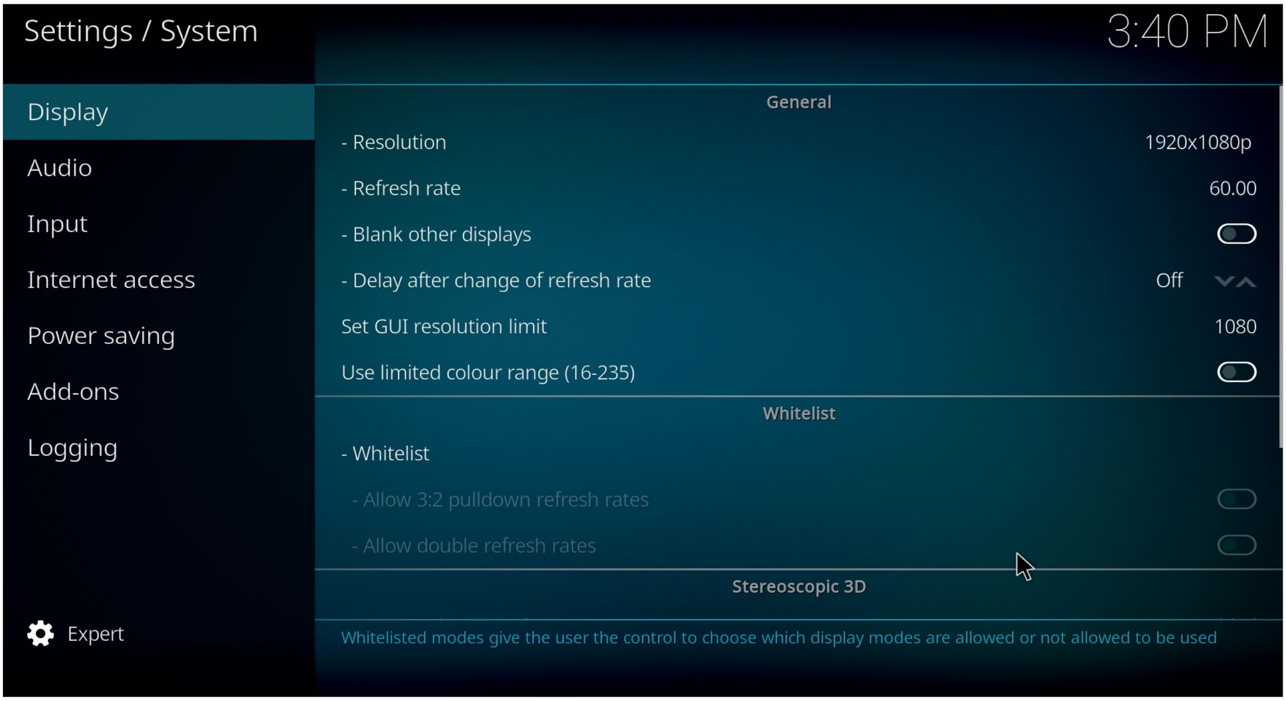
MAKING AND BOOTING a LibreELEC SD card follows much the same procedure as any other Pi operating system you would care to name. You just need to ensure you use the correct image. LibreELEC 10 supports the Pi 4, Pi 3, and Pi 2 with the latest version. Download the image from the releases page at https://libreelec.tv/downloads/raspberry/.

For Pis Zero and 1, use the latest image from the previous 9.2 series, which you'll find by scrolling down. Or consider one of the 'other' boards supported by the new edition, such as the Pine64. There's also a generic image for running on a regular 64-bit PC or a ready-to-go virtual machine image. There's an official LibreELEC USB-SD Creator app for macOS, Linux, and Windows but it didn't work that well for us, so we'll continue to recommend Balena Etcher for this purpose. See the install page on the wiki https://wiki.libreelec.tv/installation/create-media if you have any problems.

Once you've made and booted your SD Card, you'll be greeted with the LibreElec splash screen followed by the Kodi setup wizard. You'll probably need a keyboard, mouse or gamepad plugged in to navigate this. But if you have plugged everything into an HDMI receiver with a remote control, then you can use that because Kodi supports the CEC (Consumer Electronic Control) protocol too. Magical! Keen-eyed readers might notice a CEC adaptor being detected during the setup stages.

On the subject of HDMI, if you want to watch 4K content at 60fps, or make use of any HDR features on your display, check that all your hardware is HDMI 2.0 compliant. HDMI 1.4 can manage 4K at low framerates, but 4Kp60 requires newer hardware and cables. If you're planning on watching content protected by HDCP 2.2 (the newest iteration of High-bandwidth Digital Content Protection), which is a lot of the 4K content out there, then you'll need to ensure all the devices in the processing chain support this (from the machine running Kodi, via a digital receiver, to your display). Since the Pi doesn't support HDCP, we won't get into that here. Most modern graphics cards and chips now support HDCP 2.2, so if you want to view such content then try running Kodi on your desktop or laptop.

Select your language and hit Next to begin the setup. The first step is to choose a hostname. The default LibreELEC is fine if you can't think of anything better. If you aren't already connected over Ethernet, you'll be presented with a list of wireless networks. Choose one so that Kodi can update itself, set the time and then download media. Next, you'll activate Samba for sharing and optionally configure SSH if you want proper remote access. Like Raspberry Pi OS, LibreELEC has a default SSH password that you should change if you turn on SSH here. Unless you have a pressing reason to activate this, it's wise to leave SSH off. Stray Pi's



General

- Resolution 1920x1080p
- Refresh rate 60.00
- Blank other displays ○
- Delay after change of refresh rate Off
Set GUI resolution limit 1080
Use limited colour range (16-235) ○

Whitelist

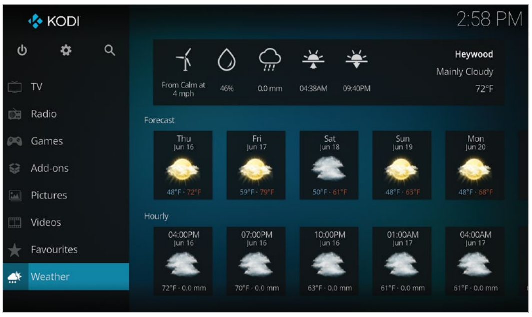
- Whitelist
- Allow 3:2 pulldown refresh rates ○
- Allow double refresh rates ○

Stereoscopic 3D

Whitelisted modes give the user the control to choose which display modes are allowed or not allowed to be used

© LIBREELEC

Getting everything going at 1080p should be trivial; higher resolutions may require manual intervention.



Enable the weather add-on feature in Kodi and you'll know if you need to take an umbrella or your shades.

running SSH (especially with well-known passwords) could turn into beachheads from which attackers can infiltrate your network. We'll turn this on later when we start messing with Kodi under the hood.

Get to know Kodi

Now you can begin exploring the Kodi interface. Navigation is intuitive, just click on menus to open them, and use Escape (or the right mouse button) to go back. The hardest part is remembering which options live where. Oh, and if you open the menu while media is playing things can be a little confusing until you remember that clicking anywhere outside of that menu will get you back to your media. But we're getting ahead of ourselves because we haven't added any media yet.

For testing purposes, the easiest way is to use the already set up Samba share to copy some media to the SD card. That share will show up under WORKGROUP on your Windows Network, and you should be able to connect to it from any platform. Use the TV Shows or Videos folder depending on what kind of content you're adding, and your media should be available from the corresponding section of Kodi's Video menu.

We won't get far if we're relying on an SD card for media storage. So it should come as no surprise that Kodi can handle all kinds of other media sources. Besides local USB storage, you can connect shares from your Windows (or Samba), or use NFS if you have media on a file server. LibreELEC can talk to many PVR/DVR (Personal/Digital Video Recorder) devices too, as well as budget DVB sticks. We didn't have any of that kind of hardware to hand, so for this feature, we'll look at setting up popular (and legal!) streaming sites.

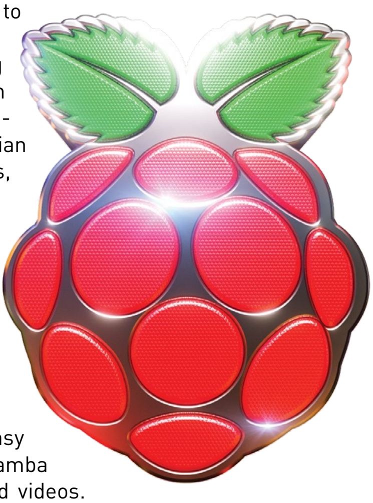
Personally, we can't get enough of streaming video services, and most of the big names are here. Go to Add-ons → Video add-ons and select Download. You'll see a big list of official sources, including HBO Go, Plex, and Netflix. Scroll down to the service you use, click it and select Install. Kodi will spring into life, grab a couple of dependencies, and before you know it there will be a link in your Add-ons → Video add-ons section.

There's no web page-like view for browsing content, as everything in Kodi is done through cascading menus. You'll get used to this and, indeed, might start to prefer it, especially as opposed to YouTube's cramped web interface, which we'll obviate over the page. Go into your chosen app and get stuck into whichever box set you're currently bingeing upon.

Next up, we'll install the Weather feature. For this, we need to enable a weather add-on within Kodi. From the main menu select Weather → Service for weather information → Get more and select the Gismeteo provider. Now open the weather's settings page and configure your location. If you want temperatures in a different measurement, go to Settings (the cog icon on the main menu) → Interface → Regional and change the Region default format setting to your locale.

One of the advantages of using LibreELEC is that it comes with a battery of Kodi add-ons pre-installed. These are mainly utilitarian additions, taking the form of codecs, libraries, and userspace tools, rather than anything that connects you directly to the content. But there's no shortage of things Kodi can stream media from. There's no doubt that having a NAS in your home to store anything can add immeasurably to the media player experience.

Media from such devices is easy to find, just add the relevant Samba share from Videos → Files → Add videos. See https://kodi.wiki/view/HOW-TO:Create_Video_Library for best practices on how to organize media before adding them to Kodi. See the box on how to get the Netflix add-on installed, and consider adding the LBRY, Soundcloud, or Bandcamp add-ons too, if you'd like to see that content on your media center.



LIBREELEC-FLIX AND CHILL

The Netflix add-on isn't in the official Kodi repos, but you can still use it if you have a Netflix account. To find the link to the repository file, go to https://github.com/CastagnaIT/plugin.video.netflix#quick-download-links then save the relevant ZIP file, either by enabling SSH via the Kodi Settings and using `wget` or by saving it from your browser into one of Kodi's Samba shares.

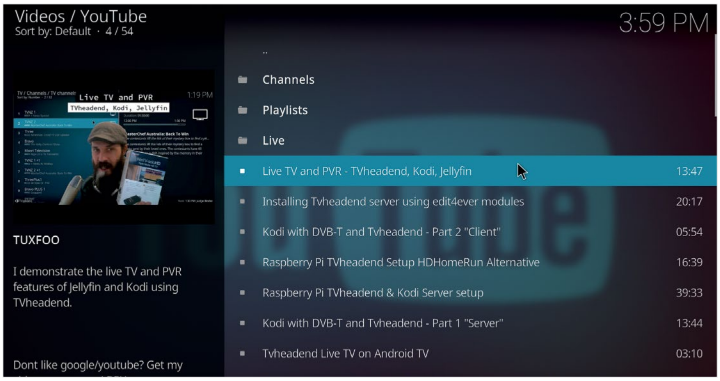
Navigate to the Add-ons browser and select Install from Zip File. Then Direct Kodi to wherever you saved the file. You'll be told that installation from unknown sources has been disabled, and directed to Settings → Add-ons → System → Unknown sources to enable it. Now return to the Add-ons browser and select Install from Repository → CastaganalT → Video add-ons → Netflix . You'll be prompted to install the InputStream Helper.

Now you can find the Netflix add-on in the Video-addons section, so fire it up. You'll be prompted to install the InputStream Adaptive add-on. You'll see a warning about changes at Netflix which mean that username and password verification may not work. Our credentials were recognized, but if yours aren't, try the keyfile authentication method instead. Instructions can be found on the project's GitHub at https://github.com/CastagnaIT/plugin.video.netflix

When you play something you'll be interrupted by a prompt to install the Widevine DRM libraries, and accept some terms—1GB of downloaded Chrome OS recovery image and a painless extraction later, your media will start playing.

HI-FIDELITY KODI

Integrate the world's most popular streaming site into Kodi and see how the Pi fares at high-resolution



Videos / YouTube
Sort by: Default · 4 / 54

3:59 PM

TUXFOO

I demonstrate the live TV and PVR features of Jellyfin and Kodi using TVheadend.

Dont like google/youtube? Get my

..	
Channels	
Playlists	
Live	
Live TV and PVR - TVheadend, Kodi, Jellyfin	13:47
Installing Tvheadend server using edit4ever modules	20:17
Kodi with DVB-T and Tvheadend - Part 2 "Client"	05:54
Raspberry Pi TVheadend Setup HDHomeRun Alternative	16:39
Raspberry Pi TVheadend & Kodi Server setup	39:33
Kodi with DVB-T and Tvheadend - Part 1 "Server"	13:44
Tvheadend Live TV on Android TV	03:10

Tuxfoo will tell you all you need to know about using DVB sticks with TVheadend and connecting that to Kodi.

SINCE THE RASPBERRY PI 4 has significantly more graphical horsepower than its predecessors, it's capable of playing 'movie' 4K resolution (i.e. 4096 x 2160 as opposed to 'TV' 4K which is 3840 x 2160) and 10-bit (HEVC) content. It might not yet be capable of driving two 4K displays at 60Hz, but it can certainly drive one.

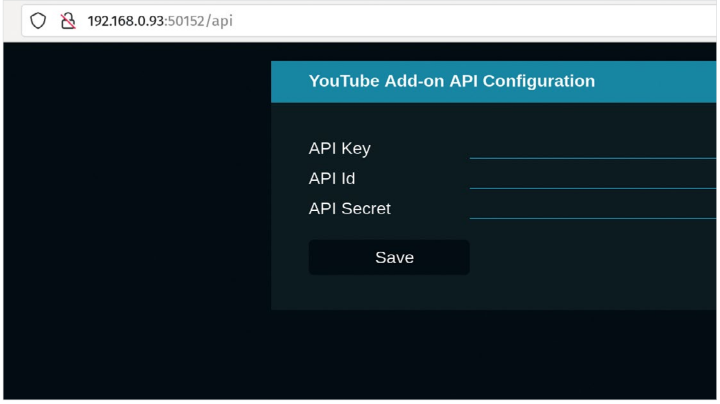
You need to enable that feature by hand, as it will make the SoC run a little warmer than usual. You'll need to enable SSH access and log in to your Kodi box to do this, remembering that Kodi has only one account, namely root. So the incantation will look like `ssh root@192.168.x.x`. Remember you can always find Kodi's IP address from the status panel.

Once you're in, you'd usually run `raspi-config` to enable this, but LibreELEC doesn't include this program. Instead, you'll have to remount the /flash partition in read-write mode and edit config.txt manually. This is straightforward:

```
$ mount -o remount,rw /flash
$ nano config.txt
```

Now add the line `hdmi_enable_4kp60=1` exit Nano, and restart.

If you don't get any joy, make sure you're using the HDMI0 port, ie. the one nearest the USB-C port used for power. HDMI1 can only manage 4Kp30 tops. If you have a gaming monitor or another display that supports high refresh rates, then you should check out the official documentation at https://www.raspberrypi.com/documentation/computers/config_txt.html.



192.168.0.93:50152/api

YouTube Add-on API Configuration

API Key
API Id
API Secret

The add-on's page for entering API keys looks like this. You can copy and paste the values from Google into here.

That will tell you how to set HDMI timings through the `/boot/config.txt` file. For 4K HEVC content, you'll need to adjust the graphics/system memory split. Anecdotal evidence suggests the GPU will need at least 340MB here, which again requires manual config.txt intervention. You might not have any 4K content, and you certainly won't be streaming that resolution through Netflix running on Kodi (or indeed any platform other than an official app). But there's plenty on YouTube if you look around.

Yikes! We've just run into our first problem, we currently have no way of viewing YouTube content on Kodi. Let's try and fix that. Navigate to Settings → Add-ons → Install from repository → Kodi Add-on repository → Video Add-ons and then select the YouTube add-on. Don't worry, we won't be touching any unofficial add-ons here, this one's safe to install, so hit install. You'll be prompted to run the setup wizard, which lets you choose your language and region. Skip this step if you don't care about locale settings, or don't want to share this information with Google (a stand that will be nullified when we hand over our API key later).

Tap into YouTube content

In the video Add-ons section, there's an icon for YouTube but it doesn't work—try it if you don't believe us. YouTube doesn't really like its content being watched through unofficial applications, the company isn't even entirely supportive of it being watched on its own website without being logged into a Google account.

The way around this is to register a new project with the Google Developers site, grant this project access to the YouTube Data API, and then connect the YouTube Add-on to this project. Effectively, you're pretending that the add-on is your own project (which the developers of said add-on are fine with, that's why the instructions tell you to do it).

Open a browser (on your PC) and navigate to https://console.developers.google.com/apis/library and log in with your Google Account. Click Create Project and give it a meaningful name, "KodiTube" for example. Don't try and do this with a corporate Google account, as you will need permission from your organization to add projects this way and you'll get an error message if you don't have it.

Once the project is set up, select Enable APIs and Services. Type the first few letters of YouTube and select YouTube Data API v3. Click through and enable the API, then click Create Credentials. Select the YouTube Data API and then select Public Data. Click Next and you'll be

© TUXFOO

presented with your API key. Don't worry about losing this as it's always available from this dashboard.

Get configuring

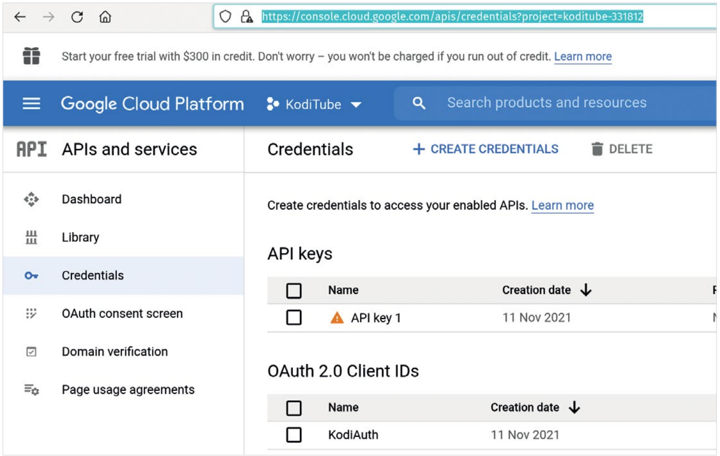
We're not done with it yet though. Click Done and then click on Configure Consent Screen. Select the External user type and click Create. Give your app a name (use the same as the Project Name, if in doubt) and set the support email to your own (don't worry, none of this will be public or seen by the Kodi add-on developers). Also, set the developer email at the bottom (everything in between can be left blank), then click Save And Continue. We don't need Scopes or Test users just yet so click through these screens until you're presented with a summary of your app registration.

Click on Credentials on the left, then Create Credentials at the top (again). This time choose Oauth client ID, select Desktop App for the Application Type, and come up with a name for your client. Again the name doesn't really matter so let's go with `Kodi-auth`. You'll be given a Client ID and Client Secret. Again, don't worry about losing them, they will still be here when you come back.

Instead, worry about how you're going to enter these lengthy and misreading-prone strings into Kodi. Fortunately, we don't need to enter these manually (although you can if you want). A less frustrating approach is to right-click the YouTube add-on and select Settings. In the API section check the box next to Enable API configuration page. Return to the browser and the Google developer page (or navigate back to that tab if you didn't close it), then open a new tab pointing at http://192.168.x.x:50152/api, replacing 192.168.x.x with your Kodi device's IP address. Go to the Credentials section in the Google Tab and copy the API key, then paste it into the first box on the KodiTube API page. Repeat for the Client ID and Client Secret (from the OAuth section) and click Save. Then return to the YouTube Add-on's settings page and disable the API page—awkward transcription exercise circumvented.

By this point, you should be able to use the Add-on to search videos (and enjoy not having ads directed your way as you do so). We're not quite done yet though, because we won't be able to sign in (and see YouTube subscriptions and recommendations) until we've added our user as a test user. Go back to the Developer Dashboard and in the Oauth consent screen section, scroll down to Test users and add your Google account. In theory, you can add up to 99 friends and save them some of the bother of this setup (they'll still need to set up API keys), but let's focus on number one first.

Now return to Kodi and open the YouTube Add-on. Click sign in, and you'll be told you have to sign in to not one but two apps. Scribble down the first one-time code, then go to google.com/device (on another device) and enter the code. You'll see a warning about Google not having verified this app, which you can safely ignore by clicking Continue. Then comes another warning that the add-on wants to access your Google account, this too you



https://console.cloud.google.com/apis/credentials?project=koditube-331812

Start your free trial with $300 in credit. Don't worry – you won't be charged if you run out of credit. Learn more

Create credentials to access your enabled APIs. Learn more

API keys

☐	Name	Creation date ↓
☐	API key 1	11 Nov 2021

OAuth 2.0 Client IDs

☐	Name	Creation date ↓
☐	KodiAuth	11 Nov 2021

The Google Cloud Platform isn't the most inspiring place to hang out, but you will be rewarded with graphs and usage credits.

can safely Allow. Now you should see a new one-time code, so once again visit google.com/device and agree to the terms. Finally, you can now browse YouTube. This worked for us anyway, the add-on page suggests that if it doesn't work for you then you should try turning on the Allow Insecure Apps setting in your Google Account.

But why support the Google monoculture? Consider getting your audiovisual entertainment from decentralized or otherwise FOSS-friendly services such as PeerTube. Installing that is, you'll be pleased to hear, markedly easier than installing YouTube. Check out the wiki at https://framagit.org/StCyr/plugin.video.peertube/-/wikis/home

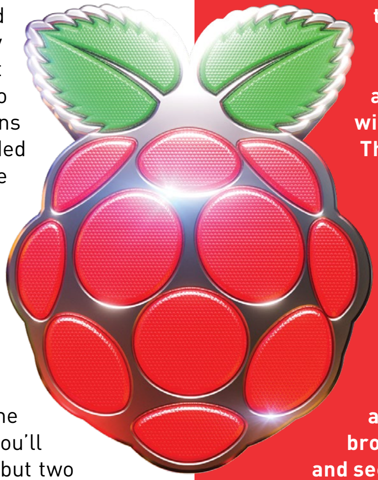
© GOOGLE

GAMING WITH KODI

Besides entertaining you with moving pictures and sound, it would be nice if Kodi could play some games too. We were hoping it would be straightforward to get Steam Play working with it but, alas, that was wishful thinking. There's a Steam Community add-on in the official repos, which has much the same functionality as the Steam Android app—letting you browse the store and see your library. If you're using Kodi on a PC that has Steam installed, then you can install the Steam Launcher add-on (again from the official repo), which integrates Steam in Big Picture Mode into Kodi.

We thought Kodi would be quite fun for retro gaming, and indeed there is a Kodi add-on called RetroMania which used to be pretty good, but we were unable to get it working with the new release. What we did have fun with was the Internet Archives retro games collection. Have a look at Kodi game add-on repository (alpha) and add the Zach Morris Add-ons. Then use the Install from Repository option and navigate to Game add-ons → Game providers → Internet Archive Game Launcher.

Besides that, you can install classics via MAME and DOSBox, which you'll find in the LibreELEC add-ons repository, in the Emulators section. There are also lots of standalone games to enjoy, including *2048*, *Mr. Boom* (a *Bomberman* clone), and *ScummVM*.



TRIPPING THE LIGHT FANTASTIC

Add a touch of pizzazz to your media center with a border of colorful, picture-reactive LEDs

YOU MIGHT HAVE SEEN the Ambilight system found on some Philips TVs, sometimes also known as Bias Lighting. The idea is quite simple: a perimeter of RGB LEDs is fixed to the back of the television, which lights up in correspondence with what's happening on screen. This has the effect of extending the image onto the walls behind the screen. There are several approaches to recreating this system with open source tools and plugging this into Kodi. The most popular is called Hyperion, which has been around for about as long as Ambilight TVs. Hyperion is flexible and a common setup is to have Kodi running on a device, say your PC, and connected to an HDMI splitter and capture device. The HDMI capture is then sent via USB to a Pi running Hyperion, which drives the LEDs.

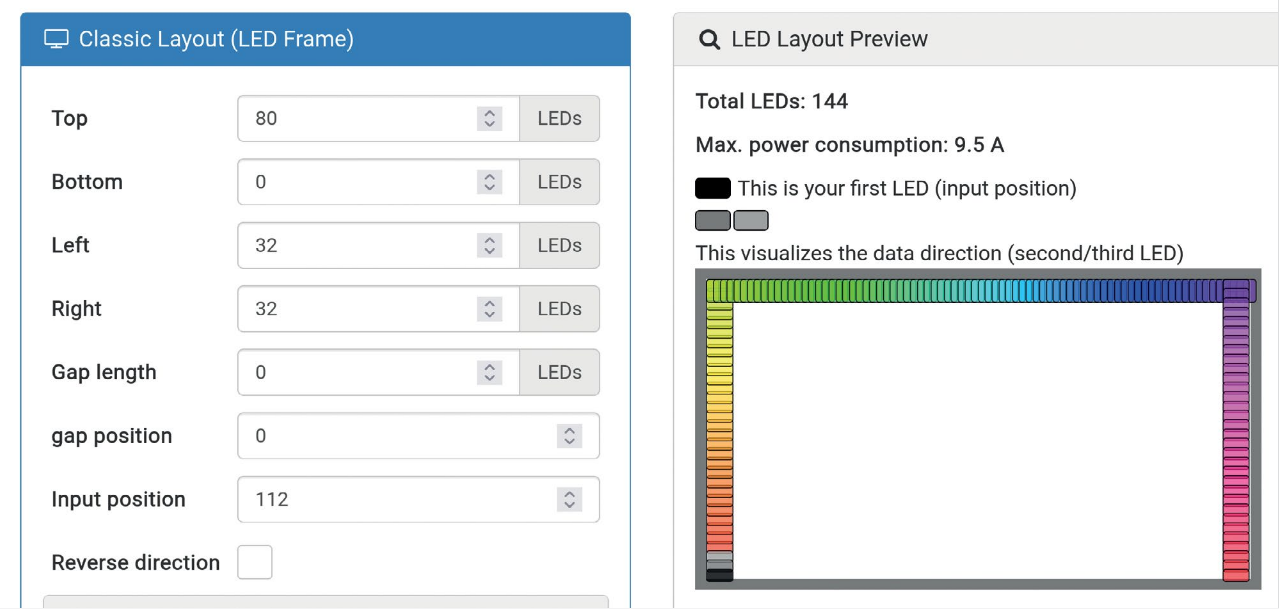
That setup is a little complicated for our liking, so we thought we'd try and come up with our own, ideally with fewer moving parts. Annoyingly, there's no way to run everything on a Pi 4, since no one has figured out how to reliably capture the frame buffer. So to use the latest Kodi, we'd need to invest in some capture hardware, either in the form of a loop capture (if we were to do everything on the Pi) or separate splitter and capture devices (if the Pi is just running the LEDs). Both of these can be achieved for under £20 with a search on Amazon.

The advantage of using a capture device is that you can use it for whatever HDMI input you happen to be watching, so your Pi can ambient light your Smart TV's interface, your desktop background, or the frantic explosions from your CS:GO exploits. Instead, we'll go back in time briefly and use Kodi 18 on a Pi 2 or 3. You could also use Kodi 19 builds now that they are available for these devices, but we set this up prior to its release. You'll find all LibreELEC releases on the downloads page, or you could take a standard Raspberry Pi OS install and augment it with Kodi. It's in the official repos so that would be just a matter of `sudo apt install kodi`.

Get configuring

The Hyperion-NG (successor to the original Hyperion) software doesn't currently use Kodi's plugin system. So to install it, we'll need to set up SSH access and fetch it ourselves. And this is where you realize that "Just Enough OS" is entirely accurate. Usually, on the Pi, we're used to installing things from the repos with Apt, or at a pinch installing packages manually with Dpkg, but neither of those tools is present on LibreELEC. Fortunately, the Hyperion developers have created a handy script to get everything installed and set up. Before you use it though, check the relevant thread on the Hyperion forum at https://hyperion-project.org/forum/index.php?thread/10463-install-hyperion-ng-on-libreelec-x86-64-rpi-inoffiziell-unofficially/ in case anything has changed.

We found the script had a typo that caused it to fetch the ARMv6 build of the software. If this bothers you (it bothered us) follow these instructions instead. SSH into the Pi, download the script, and edit with:



Classic Layout (LED Frame)

Top	80	LEDs
Bottom	0	LEDs
Left	32	LEDs
Right	32	LEDs
Gap length	0	LEDs
gap position	0	
Input position	112	
Reverse direction	☐	

LED Layout Preview

Total LEDs: 144

Max. power consumption: 9.5 A

■ This is your first LED (input position)

■■ This visualizes the data direction (second/third LED)

Use the LED Numbers button to tell Hyperion the Input Position (where the LED strip starts).

© HYPERION

```
# wget https://git.io/Jz5Qp -O hyperion.sh
# nano hyperion.sh
```

Now scroll down to the lines beginning:

```
RPI_1=...
RPI_2_3_4=...
```

Remove the `\|BCM2835` from the RPI_1 line, and add it to the line beginning RPI_2, so that it now begins:

```
RPI_2_3_4='grep -m1 -c 'BCM2709\|BCM2710\|BCM28
35\|BCM2836...
```

Most Pi 3 and 4s it turns out report the BCM2835 SoC, so this was not a reliable detection scheme. Nevermind, we've fixed it now, so we can go ahead and run the script with:

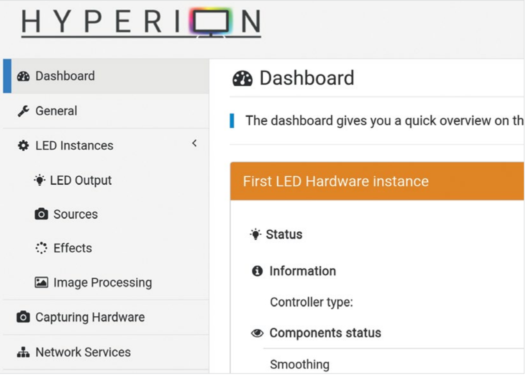
```
# bash hyperion.sh
```

The script will automatically modify config.txt to enable the SPI bus and allow communication with your LEDs, but this will require a restart to take effect. Once you do that, Hyperion will be running in the background, ready to light things up. So let's arrange some lights, but first, check the box for some words of illumination.

As you may have gathered, there will be some wires involved in this setup, but no soldering is needed and it all fits nicely on a breadboard. Since we have two power sources (the Pi and the LEDs' power source), we need to establish a common earth. Otherwise, we'll start introducing ground loops (where current flows from one "0V" rail to the other, because potential is relative). This is fairly straightforward though, simply connect the Pi's GND to the negative rail on our breadboard.

Of course, it's then tempting to connect the Pi's 5V line to the breadboard too, but we wouldn't recommend doing this. If you were to accidentally turn off your LEDs' power source and then try and use them, they will then try and draw power from the Pi, which will be fine for a couple of blinkenlights, but won't work (and may even damage) anything more than that.

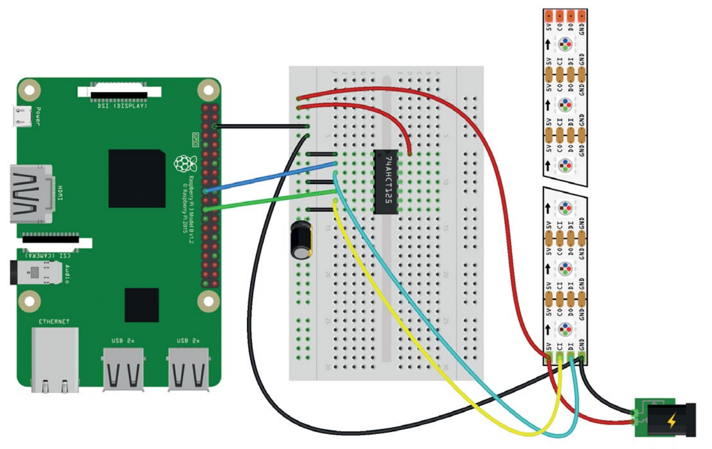
Rather than start arguments about GPIO pin numberings or how much power to provide to one's Neopixels/Dotstars, we'll show you how we set ours up. One thing we learned is that while it's common for the +5V and 0V wires to be red and black, and at opposite sides of the connector, the clock and data lines seem to move around between manufacturing runs. So the wiring might not agree with any diagrams given by the manufacturer or vendor. One symptom of clock and data being wired backward is LEDs not lighting as commanded, but with occasional wild flickering if you gently wiggle the breadboard connections.



The dashboard gives you a quick overview on th

Controller type:

Hyperion's web interface makes configuring tiny blinking lights an absolute charm.



This looked much less tidy in real life. Pro tip: the negative end of a capacitor has a stripe on it.

If you can't get something working, visit the Hyperion web configuration page at http://192.168.x.x:8090, again replacing the IP address with that of your LibreELEC box. The first step is to tell Hyperion about the nature and number of our LEDs, which is done from LED Instances → LED Output. We set the Controller type to apa102 and set the SPI Device to 0.0 (we used GPIO pins 10 (MOSI) and 11 (SCLK) for the data and clock lines).

Now set the Hardware LED count to the number of LEDs you have, save settings and proceed to the LED Layout tab. Configuring the layout is straightforward, and then you can test things are working by selecting Remote Control and picking random colors and effects. Activate Screen Capture in the Capturing Hardware section, and your LEDs should fluoresce into life. ⏻

THE TAO OF LEDS

There's plenty of good information about how to wire LEDs properly, and you should study this rather than trust our brief explanation. But there are also some important pointers which we must impart.

LEDs can use a lot of power (up to 60mA each at full brightness), so if you have a few, you'll need an external power source. We used a 5A power supply for our 144 APA102s, known as "DotStars".

As well as a 5V power source, most programmable LEDs also use 5V for their data (and clock in the case of APA102s) lines. This is problematic because the Pi uses 3.3V logic. Solutions include doing nothing (some LEDs will manage with the lower voltage) or using a diode or pair of resistors (to make a potential divider).

Neither of these is quite satisfactory though, and since we already have an external 5V supply, we may as well use that with a level shifter. We used the popular 74AHCT125 chip, which can boost not one but four inputs. This is good as both the clock and data lines need shifting on our DotStars.

Also, as you add more and start doing ever more complicated effects with LEDs, residual currents will start to flow up and down the cable, causing unwanted effects (and possibly damage).

A capacitor placed across the power source acts as a reservoir for this current, and we definitely needed one for our 144 LEDs. We used a 330-microfarads one, but the guidance suggests anywhere between 100-1000 should do the job nicely.

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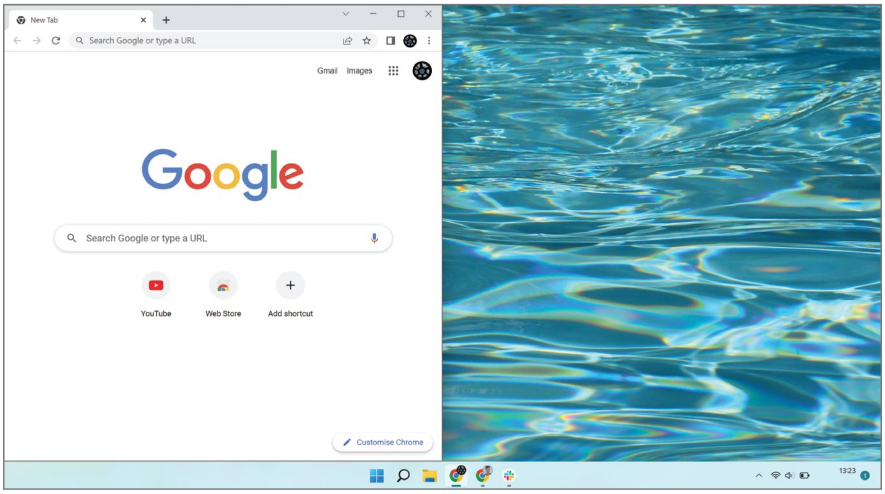
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

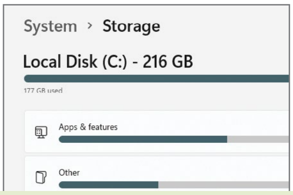
TIP OF THE MONTH



RESIZE YOUR WINDOWS

Instead of moving your mouse to the edge of an open window and dragging it to size, there's a slightly quicker action that should help you organize your desk space more efficiently. Holding down the Windows key and simultaneously pressing an arrow key will move your active window around according to which arrow key you use. Pretty nifty, right?

MAKE – USE – CREATE

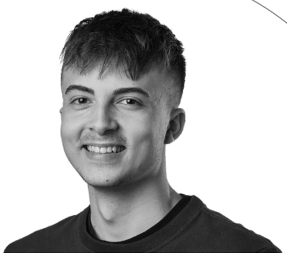


58
Free up disk space with Windows 11 cleaning tools

64
Make a 3D map effect from your photos in GIMP

66
This month's Build It features AMD's latest budget GPU

© MICROSOFT, GIMP



SAM LEWIS
STAFF WRITER

PLANE PAIN

After only running the latest *Lego Star Wars* title on our new liquid-cooled PC build, I thought it'd be criminal to not push this mighty machine further. I haven't played *Elden Ring* yet—I'm currently moving house, so I need to settle in first before I can commit to it.

In the meantime, I've been playing *Forza Horizon 5* with a racing wheel and it's a breeze. There's an almost eerie feeling when running this PC as it barely needs to use the fans. Working on PCs all week, you get used to the background noise, so the lack of it is really noticeable.

As well as moving house, I've not long come off my holiday and I can tell you one thing, as good as active noise-canceling is, it doesn't help if you are sat at the front of a plane. On the flight back, I needed to sleep as we landed at 3am and I had a further three-hour drive home. I'd brought B&O Beoplay Portal headphones and thought I'd be able to easily zone out using ANC.

As good as they are though, they didn't stop people knocking past me in the front row aisle seat. Every time I was drifting off, someone bumped into me and technology can't yet fix that. Other than that, these headphones are so versatile for films and music and were perfectly comfortable over the four-hour flight. If only the aisles were a little wider.

↘ submit your How To project idea to: editor@maximumpc.com

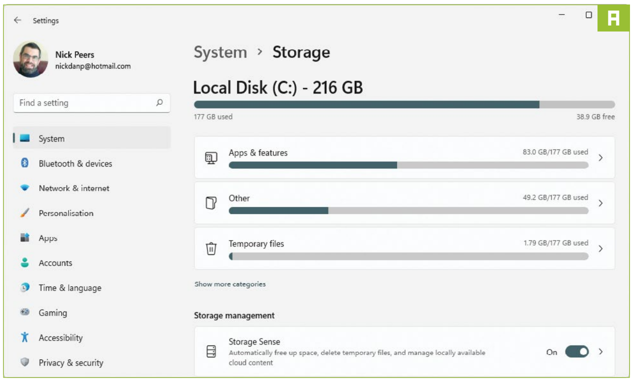
Clean Out Windows 11

YOU'LL NEED THIS

YOU WILL NEED SOME OR ALL OF THE FOLLOWING TOOLS:
Bulk Crap Uninstaller, CCleaner, TreeSize Free, Awesome Duplicate Photo Finder, SteamMover (all free)

THE EMERGENCE OF SMALLER, faster boot drives has resurrected an age-old problem: how to stop your hard drives from filling to capacity. What wasn't such an issue with a 2TB drive is now a hot topic as you struggle to maintain Windows 11 and your apps on a super-speedy 256GB NVMe boot drive. In this tutorial, we'll reveal a range of tips, techniques, and tools to help you bring back some semblance of order to your drive's contents while ensuring you have plenty of room to allow your personal files to sit side-by-side with Windows, your games, and other apps.

We'll start with a quick tour of Windows' own cleaning tools—all conveniently accessible via the System → Storage section of Settings—before going deeper and using the best free tools to thoroughly remove multiple apps in one go, perform a deep clean of areas Storage Sense couldn't reach, plus help thin out your gargantuan photo collection so only the best version of each photo is kept. And if that still isn't enough to free up the space you need, discover how to safely move apps to another drive with just a few clicks. **–NICK PEERS**



System › Storage

Local Disk (C:) - 216 GB

177 GB used — 38.9 GB free

Apps & features — 83.0 GB/177 GB used

Other — 49.2 GB/177 GB used

Temporary files — 1.79 GB/177 GB used

Show more categories

Storage management

Storage Sense — Automatically free up space, delete temporary files, and manage locally available cloud content — On

1 GET AN OVERVIEW

Start your cleanup by opening Settings and navigating to System → Storage. You'll see a bar chart revealing your system disk's current capacity and how much space has been filled. Beneath this is a list of categories revealing where much of that space has gone—Apps & Features, Other, and Temporary files are shown by default [**Image A**]. Click one for a more detailed look or click 'Show more categories' for additional views of your personal files, the desktop, and OneDrive storage.

›› While useful, Settings doesn't provide a full overview of the drive—if you're looking for an alternative way to visualize the missing space on your drive, check the box.

2 CLEAN YOUR DRIVE

When examining your drive in-depth, you'll be given an opportunity to delete file types, such as those classified as temporary files [**Image B**]. Scroll through the list checking any items you want to get rid of before clicking 'Remove files'.

›› It's a similar procedure with other drives. To view their contents, click 'Advanced storage settings' under System Storage, followed by 'Storage used on other drives'. Click on the drive to view a breakdown of how the space is used.

›› Each category comes with a link beneath it to help manually clean up files in that category. In some cases, such as Music, Videos, or Other (for large folders), you'll be shown a list of folders (sorted by size), allowing you to click any items to open the folder in File Explorer to review and delete its contents.

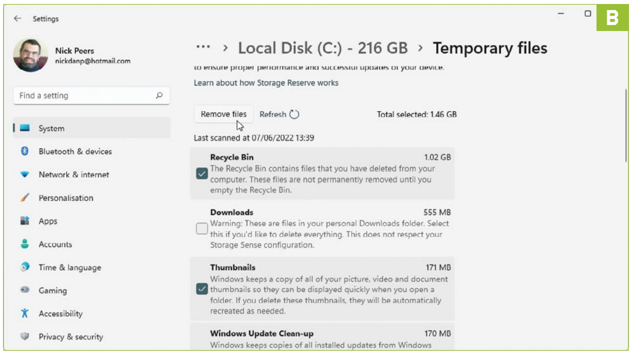
›› Other categories, such as Recycle Bin and Temporary Files, will take you to a new screen where you'll be shown a list of options with checkboxes. These work in the same way as with the main Windows system drive—check those you want to delete before clicking the Remove button.

3 STORAGE SENSE

Wading through your drives manually is time-consuming, so Windows has introduced a more dynamic clean-up tool in the form of Storage Sense. This can be configured to automatically keep an eye on your hard drive(s), freeing up space as and when required. You'll see a switch next to its entry under System → Storage for turning its automatic features on or off; click Storage Sense itself to configure it further.

›› You'll see a handy checkbox for keeping the unruly temporary files introduced by Windows and third-party apps in check, along with options for scheduling when Storage Sense should run. The default is whenever disk space runs low, but you can run it on a daily, weekly, or monthly basis if you prefer. You can also configure Storage Sense to empty the Recycle Bin and your Downloads folder after a specified period if you wish. Once done, click the 'Run Storage Sense now' button if you'd like it to manually clean your PC.

›› Windows' Storage tool also offers recommendations on how you can clear up more space—how much is listed



··· › Local Disk (C:) - 216 GB › Temporary files

to ensure proper performance and successful updates of your device.

Learn about how Storage Reserve works

Total selected: 1.46 GB

Last scanned at 07/06/2022 13:39

☑ **Recycle Bin** — 1.02 GB
The Recycle Bin contains files that you have deleted from your computer. These files are not permanently removed until you empty the Recycle Bin.

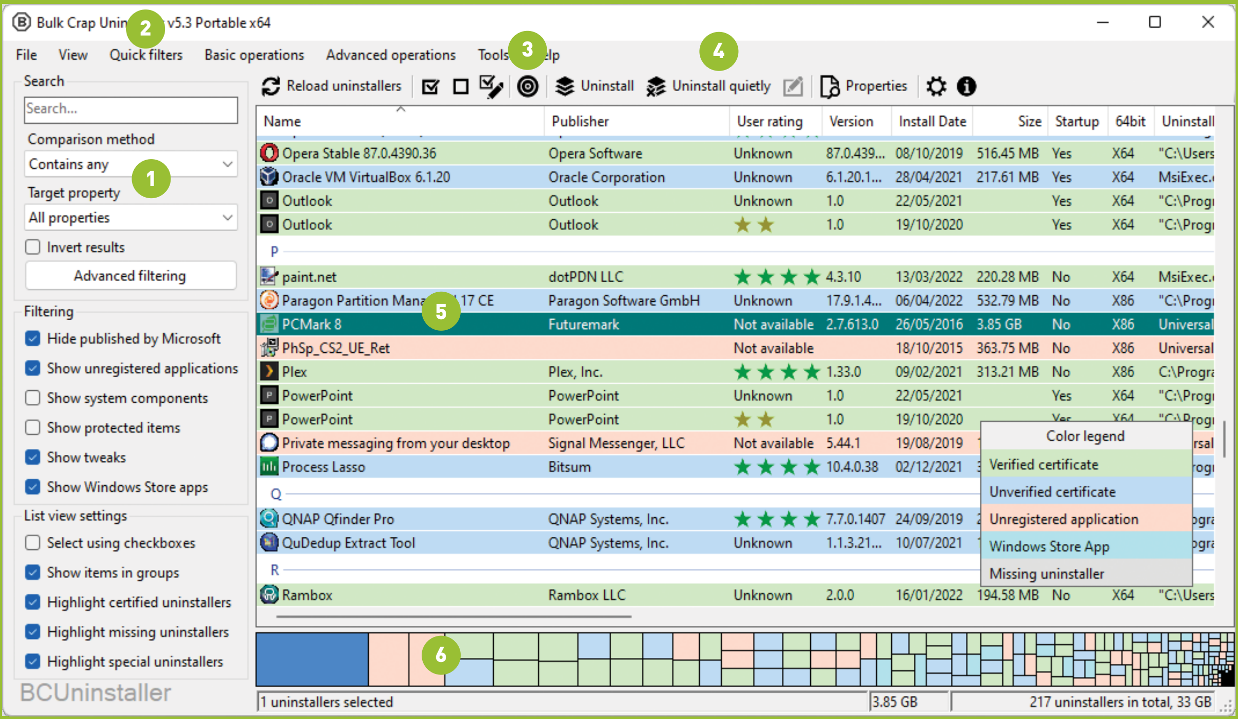
☐ **Downloads** — 555 MB
Warning: These are files in your personal Downloads folder. Select this if you'd like to delete everything. This does not respect your Storage Sense configuration.

☑ **Thumbnails** — 171 MB
Windows keeps a copy of all of your picture, video and document thumbnails so they can be displayed quickly when you open a folder. If you delete these thumbnails, they will be automatically recreated as needed.

Windows Update Clean-up — 170 MB
Windows keeps copies of all installed updates from Windows

© MICROSOFT

TAKE THE BCU TOUR



Search

Search...

Comparison method: Contains any

Target property: All properties

☐ Invert results

Advanced filtering

Filtering

☑ Hide published by Microsoft

☑ Show unregistered applications

☐ Show system components

☐ Show protected items

☑ Show tweaks

☑ Show Windows Store apps

List view settings

☐ Select using checkboxes

☑ Show items in groups

☑ Highlight certified uninstallers

☑ Highlight missing uninstallers

☑ Highlight special uninstallers

Name	Publisher	User rating	Version	Install Date	Size	Startup	64bit	Uninstall
Opera Stable 87.0.4390.36	Opera Software	Unknown	87.0.439...	08/10/2019	516.45 MB	Yes	X64	"C:\Users
Oracle VM VirtualBox 6.1.20	Oracle Corporation	Unknown	6.1.20.1...	28/04/2021	217.61 MB	Yes	X64	MsiExec.
Outlook	Outlook	Unknown	1.0	22/05/2021		Yes	X64	"C:\Prog
Outlook	Outlook	★★	1.0	19/10/2020		Yes	X64	"C:\Prog
P								
paint.net	dotPDN LLC	★★★★	4.3.10	13/03/2022	220.28 MB	No	X64	MsiExec.
Paragon Partition Mana 17 CE	Paragon Software GmbH	Unknown	17.9.1.4...	06/04/2022	532.79 MB	No	X86	"C:\Prog
PCMark 8	Futuremark	Not available	2.7.613.0	26/05/2016	3.85 GB	No	X86	Universal
PhSp_CS2_UE_Ret		Not available		18/10/2015	363.75 MB	No	X86	Universal
Plex	Plex, Inc.	★★★★	1.33.0	09/02/2021	313.21 MB	No	X86	C:\Progra
PowerPoint	PowerPoint	Unknown	1.0	22/05/2021		Yes	X64	"C:\Prog
PowerPoint	PowerPoint	★★	1.0	19/10/2020				
Private messaging from your desktop	Signal Messenger, LLC	Not available	5.44.1	19/08/2019				rsal
Process Lasso	Bitsum	★★★★	10.4.0.38	02/12/2021				rogi
Q								
QNAP Qfinder Pro	QNAP Systems, Inc.	★★★★	7.7.0.1407	24/09/2019				ogra
QuDedup Extract Tool	QNAP Systems, Inc.	Unknown	1.1.3.21...	10/07/2021				ogra
R								
Rambox	Rambox LLC	Unknown	2.0.0	16/01/2022	194.58 MB	No	X64	"C:\Users

Color legend
- 🟩 Verified certificate
- 🟦 Unverified certificate
- 🟥 Unregistered application
- Windows Store App
- Missing uninstaller

1 uninstallers selected | 3.85 GB | 217 uninstallers in total, 33 GB

1. FILTER LIST
Use these tools to either search for a specific app or to filter the list. Add more filters like 'Windows features' to the displayed options via the Settings menu.

2. QUICK FILTERS
Click here to quickly apply commonly used filters – such as showing only unregistered apps – to the list view. Choose 'Default filters' to restore the previous view.

3. UNINSTALL BY TARGET
If you have the unwanted program's window or directory open, or its program file visible, you can uninstall it quickly by clicking this button before clicking on the relevant target.

4. UNINSTALL QUIETLY
Click this button and BCU will attempt to remove all selected programs without requiring you to run through any installation wizards if possible.

5. APP LIST
Apps are color-coded by type, so use the column headers to change the sort order and select multiple apps by holding Ctrl as you click each one.

6. SIZE CHART
This chart displays apps by the space taken up on your hard drive. Click one to select the app in question—a quick and easy way to identify and remove space-hogging programs from your PC.

under 'Cleanup recommendations' beneath Storage Sense. Click this to review in more detail—Temporary Files includes the Recycle Bin and Downloads, while 'Large or unused files' targets big files that haven't been opened in a while. 'Files synced to the cloud' links in with your OneDrive account to remove local copies of uploaded files, while 'Unused apps' works in a similar way to unused files, but with apps installed through the Microsoft Store.

» Each section comes with its own 'Clean up…' button and you can easily clear gigabytes of redundant files with a few clicks.

4 REMOVE UNWANTED APPS

Another way to clean up your system is to reduce the number of apps installed. You can make use of Windows' own uninstall tools, found under Settings → Apps → Apps & Features. One time-saving tip is to use the 'Sort by' dropdown to list apps by their size to quickly identify space hogs.

» A more effective timesaver is to bypass Windows' own tool. Its shortcomings include a need to remove one app at a time, which is frustrating if you're looking to clear a few apps in one go, and that it relies on a program's uninstall utility, often leaving behind detritus such as redundant files and Registry entries.

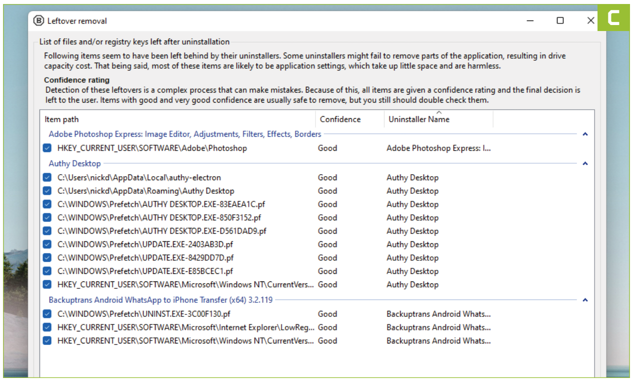
» Both problems can be fixed with a good third-party tool. We've plumped for Bulk Crap Uninstaller (BCU) because it's open-source (so free) and doesn't come with any bundleware or adds. BCU can target Windows Store apps as well as regular programs, scans for leftover files and Registry entries after programs have been removed, and can remove multiple apps in one go.

» Visit www.bcuninstaller.com to learn more about BCU and to download the installer from the link provided. Whether you choose a standard or portable installation, once complete, you'll run through the orientation wizard, then be presented with the main screen (see box above).

5 CHOOSE WHAT TO UNINSTALL

By default, apps are displayed alphabetically—use the filters on the left or the Quick Filter menu to determine what's shown. You'll see apps are color-coded—note that unregistered applications (marked in pink) aren't installed programs, but program installers. Untick 'Show unregistered applications' to remove them from view unless you want to prune redundant installers.

© BUC



List of files and/or registry keys left after uninstallation

Following items seem to have been left behind by their uninstallers. Some uninstallers might fail to remove parts of the application, resulting in drive capacity cost. That being said, most of these items are likely to be application settings, which take up little space and are harmless.

Confidence rating
Detection of these leftovers is a complex process that can make mistakes. Because of this, all items are given a confidence rating and the final decision is left to the user. Items with good and very good confidence are usually safe to remove, but you still should double check them.

Item path	Confidence	Uninstaller Name
Adobe Photoshop Express: Image Editor, Adjustments, Filters, Effects, Borders		
☑ HKEY_CURRENT_USER\SOFTWARE\Adobe\Photoshop	Good	Adobe Photoshop Express: I...
Authy Desktop		
☑ C:\Users\nickd\AppData\Local\authy-electron	Good	Authy Desktop
☑ C:\Users\nickd\AppData\Roaming\Authy Desktop	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\AUTHY DESKTOP.EXE-83EAEA1C.pf	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\AUTHY DESKTOP.EXE-850F3152.pf	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\AUTHY DESKTOP.EXE-D561DAD9.pf	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\UPDATE.EXE-2403AB3D.pf	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\UPDATE.EXE-8429DD7D.pf	Good	Authy Desktop
☑ C:\WINDOWS\Prefetch\UPDATE.EXE-E85BCEC1.pf	Good	Authy Desktop
☑ HKEY_CURRENT_USER\SOFTWARE\Microsoft\Windows NT\CurrentVers...	Good	Authy Desktop
Backuptrans Android WhatsApp to iPhone Transfer (x64) 3.2.119		
☑ C:\WINDOWS\Prefetch\UNINST.EXE-3C00F130.pf	Good	Backuptrans Android Whats...
☑ HKEY_CURRENT_USER\SOFTWARE\Microsoft\Internet Explorer\LowReg...	Good	Backuptrans Android Whats...
☑ HKEY_CURRENT_USER\SOFTWARE\Microsoft\Windows NT\CurrentVers...	Good	Backuptrans Android Whats...

» Next, select apps from the list using the Ctrl-click method before clicking one of Uninstall or Uninstall quietly. The latter attempts to remove selected applications without involving any dialog boxes, which typically require you to be poised with the mouse ready to click at the appropriate moment. Don't worry, if certain uninstallers don't play ball, then BCU will alert you.

» We recommend choosing the regular Uninstall option the first time to see how the process works. You'll be taken through a wizard, covering related applications you might wish to uninstall, followed by options to determine the type of removal and the order in which programs are removed.

» You will be shown any running programs or processes that you need to kill before reviewing global uninstallation settings, such as avoiding system restarts and how to handle quiet uninstallers. After reviewing these settings, click 'Begin Uninstallation'.

» A Restore point is taken, and then a progress bar reveals where you are with the removal process. Each program is removed using its own uninstaller and then when all are removed, click Close followed by Yes to go hunting for leftovers. A screen will reveal what files and Registry entries have been found along with a 'confidence' rating for whether it's linked to the program in question [**Image C**]. Review and click 'Delete selected' to clear more space from your computer.

» BCU will offer to back up any Registry entries, while deleted files are sent to the Recycle Bin, giving you a window of opportunity to restore them if required. Alternatively, you should be able to undo your changes by using System Restore to recover the Restore point you took at the start of the process, if necessary.

6 PERFORM A DEEP CLEAN

Redundant files hide in all sorts of places, from application folders to browser caches, and Windows' Storage Sense doesn't catch all of them. You can target these individually, but there's a range of free cleaning tools that can scoop up all these and other redundant files with the minimum of fuss.

» CCleaner (www.ccleaner.com) is the best-known tool, and while it's increasingly focused on upselling its Pro version, the free version contains all the core cleaning tools you need. As always, we prefer running portable versions of tools to prevent cluttering up your system, and you'll find the portable version of CCleaner hidden under www.ccleaner.com/ccleaner/builds. After unzipping the contents to your portable apps folder, launch CCleaner from the x64 directory and click 'Check for updates' to update its files to their latest versions.

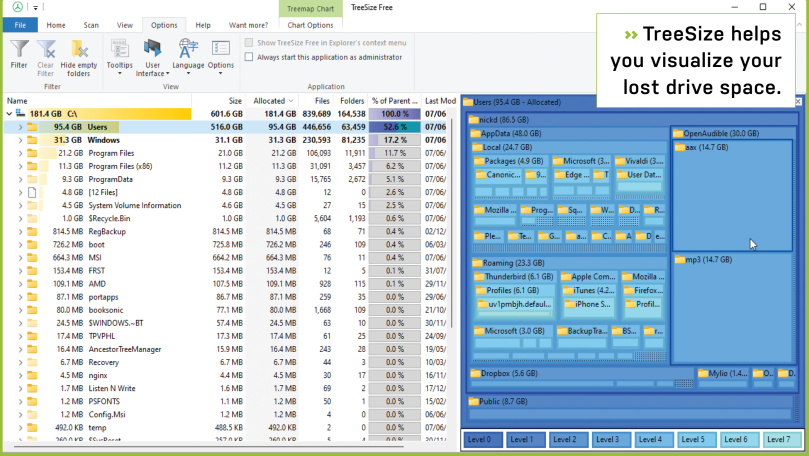
» The Health Check button can scan and provide a quick summary of items CCleaner has found (Privacy covers your browser, Space covers other potentially redundant files from Windows and apps), but for full control, we recommend clicking Custom Clean. Here, you'll see a list of categories split into two tabs (Windows covers system files and both Edge and Internet Explorer, Applications any third-party apps including other web browsers). Any checked boxes are included in the scan.

» Once you've selected what to clean, click Analyze and let CCleaner scan to produce a summary of what it's found in each category. Double-click each category to see what files are there—if you spot a file or setting you wish to keep, right-click it and choose 'Add to Exclude list' to protect it from this and future scans.

LOCATE SPACE HOGS

Knowing what files reside where on your hard drive is obviously a great help when it comes to trying to clear space. Do you need to simply target a few large files, for example, or will it require the help of third-party tools to identify the files you can safely delete?

What you need is a tool that can visualize your drives or folders in a way that's easy to understand, and TreeSize Free (www.jam-software.com/treesize_free) is one such tool in both portable and installer form. After launching, click 'Start TreeSize Free as Administrator' to gain full access to your drive. Click the dropdown arrow next to 'Select Directory' to select a drive and wait for it to be scanned.



☐ Show TreeSize Free in Explorer's context menu
☐ Always start this application as administrator

Name	Size	Allocated	Files	Folders	% of Parent ...	Last Mod
181.4 GB C:\	601.6 GB	181.4 GB	839,689	164,538	100.0 %	07/06
95.4 GB Users	516.0 GB	95.4 GB	446,656	63,459	52.6 %	07/06
31.3 GB Windows	31.1 GB	31.3 GB	230,593	81,235	17.2 %	07/06
21.2 GB Program Files	21.0 GB	21.2 GB	106,093	11,911	11.7 %	07/06/
11.3 GB Program Files (x86)	11.2 GB	11.3 GB	31,091	3,457	6.2 %	07/06/
9.3 GB ProgramData	9.3 GB	9.3 GB	15,765	2,672	5.1 %	07/06/
4.8 GB [12 Files]	4.8 GB	4.8 GB	12	0	2.6 %	07/06/
4.5 GB System Volume Information	4.6 GB	4.5 GB	27	15	2.5 %	07/06/
1.0 GB $Recycle.Bin	1.0 GB	1.0 GB	5,604	1,193	0.6 %	07/06/
814.5 MB RegBackup	814.5 MB	814.5 MB	68	71	0.4 %	02/12/
726.2 MB boot	725.8 MB	726.2 MB	246	109	0.4 %	06/03/
664.3 MB MSI	664.2 MB	664.3 MB	76	11	0.4 %	07/06/
153.4 MB FRST	153.4 MB	153.4 MB	12	5	0.1 %	31/07/
109.1 MB AMD	107.5 MB	109.1 MB	928	115	0.1 %	29/11/
87.1 MB portapps	86.7 MB	87.1 MB	259	35	0.0 %	29/06/
80.0 MB booksonic	77.1 MB	80.0 MB	1,668	109	0.0 %	21/10/
24.5 MB $WINDOWS.~BT	57.4 MB	24.5 MB	63	10	0.0 %	30/11/
17.4 MB TPVPHL	17.3 MB	17.4 MB	61	25	0.0 %	24/09/
16.4 MB AncestorTreeManager	15.9 MB	16.4 MB	243	28	0.0 %	19/05/
6.7 MB Recovery	6.7 MB	6.7 MB	44	3	0.0 %	10/03/
4.5 MB nginx	4.4 MB	4.5 MB	30	17	0.0 %	16/11/
1.7 MB Listen N Write	1.6 MB	1.7 MB	69	2	0.0 %	17/12/
1.2 MB PSFONTS	1.1 MB	1.2 MB	50	1	0.0 %	15/02/
1.2 MB Config.Msi	1.2 MB	1.2 MB	4	0	0.0 %	06/06/
492.0 KB temp	488.5 KB	492.0 KB	2	0	0.0 %	07/06/

» **TreeSize helps you visualize your lost drive space.**

Once completed, you'll see a list of folders sorted and clearly marked by size, helping identify where most space is being used. You can either drill down through the folders to identify exactly which files or folders are taking up the most space, or switch to the View tab on the ribbon and click 'Show Treemap Chart' for a handy visualization helping to pinpoint where those files are.

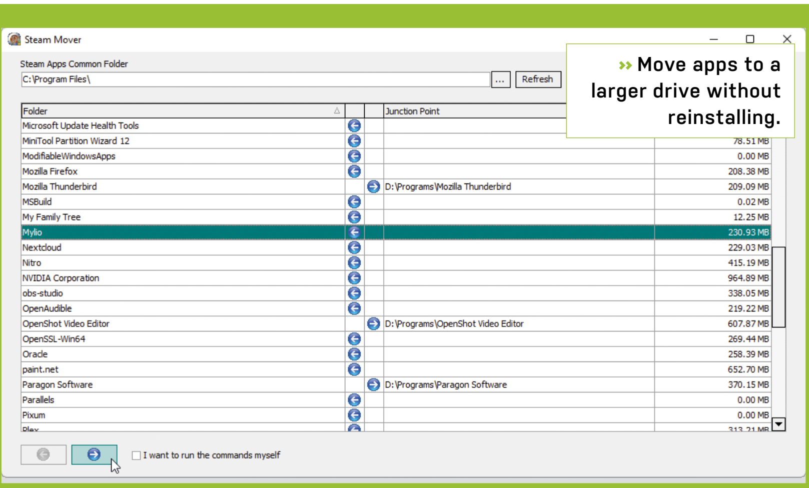
© TREESIZE

MOVE APPS WITHOUT REINSTALLING

If you're struggling to free up space on a small primary boot drive, then uninstalling apps is usually only a temporary fix, and not always practical. If you have access to another faster SSD or NVMe drive, then a better option is to move apps to that drive. Ordinarily, this requires uninstalling and reinstalling each app in turn—a time-consuming task that could result in lost settings.

Instead, download SteamMover (www.traynier.com/software/steammover), a tiny portable app that works with any application. Make sure you run the program as an administrator. Then select your current programs folder, which for most is a two-step process: C:\Program Files followed by C:\Program Files (x86). Set up a folder on your target drive, select the apps you want to transfer, and click the transfer button.

SteamMover simply moves your program folder to your new drive, then creates a special shortcut known as a junction point in the original folder pointing to the new location. Windows is none the wiser, and everything runs as before. Make sure the program and all related apps are closed before moving. If you get an error, move the folder back to its original location and try again.



Steam Apps Common Folder
C:\Program Files\

Folder			Junction Point	
Microsoft Update Health Tools	←			
MiniTool Partition Wizard 12	←			78.51 MB
ModifiableWindowsApps	←			0.00 MB
Mozilla Firefox	←			208.38 MB
Mozilla Thunderbird		→	D:\Programs\Mozilla Thunderbird	209.09 MB
MSBuild	←			0.02 MB
My Family Tree	←			12.25 MB
Mylio	←			230.93 MB
Nextcloud	←			229.03 MB
Nitro	←			415.19 MB
NVIDIA Corporation	←			964.89 MB
obs-studio	←			338.05 MB
OpenAudible	←			219.22 MB
OpenShot Video Editor		→	D:\Programs\OpenShot Video Editor	607.87 MB
OpenSSL-Win64	←			269.44 MB
Oracle	←			258.39 MB
paint.net	←			652.70 MB
Paragon Software		→	D:\Programs\Paragon Software	370.15 MB
Parallels	←			0.00 MB
Pixum	←			0.00 MB
Plex	←			313.21 MB

☐ I want to run the commands myself

» Move apps to a larger drive without reinstalling.

» Once you're happy with your choices, click 'Run Cleaner' and let the program free up space.

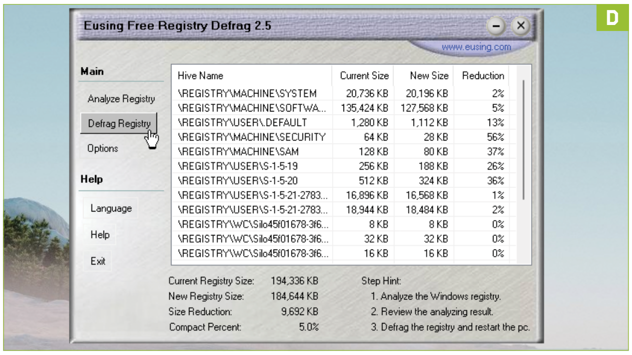
7 REGISTRY 'CLEANING'

» CCleaner also offers a tool for cleaning out redundant items from your Registry. Not only is this risky—binning parts of the Registry without due care can render applications or even parts of your system unusable—but it also achieves nothing in terms of performance. That's because when you delete items, the Registry doesn't shrink in size; like files, the 'space' isn't recovered but marked available for future entries to reside in.

» Registry entries should always be deleted manually, in context, and with care. That's why Bulk Crap Uninstaller is useful because it shows you the Registry entries it thinks can be deleted, which you can link to the application you're removing. CCleaner will also invite you to manually review each Registry entry it identifies as removable, but when there are hundreds to process it's easy to just click yes to all and damn the consequences. Make sure you back up the Registry when prompted, so you can easily restore deleted entries if things go wrong.

» You can compact and defrag the Registry's hives, the files that make up its contents. Many third-party tools exist, including Eusing Free Registry Defrag at www.eusing.com/free_registry_defrag/registry_defrag.htm [**Image D**]. But even after compaction, the effect on free drive space and performance is negligible on today's super-fast PCs.

D



Hive Name	Current Size	New Size	Reduction
\REGISTRY\MACHINE\SYSTEM	20,736 KB	20,196 KB	2%
\REGISTRY\MACHINE\SOFTWA...	135,424 KB	127,568 KB	5%
\REGISTRY\USER\.DEFAULT	1,280 KB	1,112 KB	13%
\REGISTRY\MACHINE\SECURITY	64 KB	28 KB	56%
\REGISTRY\MACHINE\SAM	128 KB	80 KB	37%
\REGISTRY\USER\S-1-5-19	256 KB	188 KB	26%
\REGISTRY\USER\S-1-5-20	512 KB	324 KB	36%
\REGISTRY\USER\S-1-5-21-2783...	16,896 KB	16,568 KB	1%
\REGISTRY\USER\S-1-5-21-2783...	18,944 KB	18,484 KB	2%
\REGISTRY\WC\Silo45f01678-3f6...	8 KB	8 KB	0%
\REGISTRY\WC\Silo45f01678-3f6...	32 KB	32 KB	0%
\REGISTRY\WC\Silo45f01678-3f6...	16 KB	16 KB	0%

Current Registry Size: 194,336 KB
New Registry Size: 184,644 KB
Size Reduction: 9,692 KB
Compact Percent: 5.0%

Step Hint:
1. Analyze the Windows registry.
2. Review the analyzing result.
3. Defrag the registry and restart the pc.

© STEAMMOVER, EUSING

8 REMOVE DUPLICATES

CCleaner also offers other cleaning tools, including a Duplicate Finder for rooting out multiple copies of the same file. However, its duplicate tool pales in comparison to standalone tools that offer a wider range of options to help weed out duplicate files, particularly images.

» A good duplicate finder will allow you to widen your search to target visually similar files, enabling you to finally pick out the best versions of all those snaps you keep taking on your phone or digital camera. If you're happy to pay, then Duplicate Files Fixer ($40, www.duplicatefilesfixer.com) covers all bases while offering dedicated tools for weeding out music, photos, and videos, which can consume vast amounts of space if left unchecked. The free trial lets you scan to see what it finds, but you'll have to pay to delete more than 15 files.

» If you're strapped for cash and are primarily targeting photos, then try Awesome Duplicate Photo Finder (www.duplicate-finder.com/photo.html). Again, a portable version is available. It's simple to use: open the app, then drag a drive or folder from File Explorer into the app window and click 'Start Search'.

» Once the scan completes, a list of files will appear at the bottom of the window, with the first image selected along with its duplicate. A similarity score indicates whether it's an exact duplicate or a close relative and by clicking the delete button next to either image you can remove the unwanted version. To avoid being prompted to confirm each individual deletion, click Settings. We'd advise against bypassing the Recycle Bin; instead, periodically empty it manually after you're happy you've deleted the right version of each file. ⏻

Machine of the Month: Oric-1 & Oric Atmos

FOR FANS OF NICHE COMPUTING, this month we look at one of history's more overlooked systems. Beautifully styled and quintessentially European, the Oric line started life in the United Kingdom's highly competitive microcomputer market, before finding a new home in France.

With the Oric line, retro gaming fans can find new variants of classic European titles, as well as titles exclusive to the system. So join us as we take a brief history tour, then show you how to emulate these computers on a modern PC. – **JOHN KNIGHT**

YOU'LL NEED THIS

A COPY OF ORICUTRON available at www.petergordon.org.uk/oricutron.

1 DEVELOPMENT AND LAUNCH – ORIC-1

The Oric line was developed by a UK company, Tangerine Computer Systems. Tangerine had already carved out a niche for itself with 1979's Microtan 65—a chunky, PC-sized 'microcomputer' aimed mostly at laboratories.

» With the release of 1982's Sinclair ZX Spectrum, Tangerine focused on the home market, intent on beating Sinclair with a better computer at a lower price. Tangerine opened a sub-company, Oric Products International Ltd, which would start with the Oric-1.

» For a CPU, Oric chose the popular MOS Technology 6502, clocked at 1MHz. Like its Spectrum rival, there would be a choice between a 16KB budget model or a 48KB version. A 32KB model was planned but eventually scrapped. A 16KB ROM ran the system with Extended BASIC licensed from Microsoft.

» Graphically, a semi-custom ULA chip provided a 40-column text mode with 28 rows and a 240 x 200 resolution, and a whole range of eight different colors.

» Sound is an Oric strong point, with a respectable General Instrument AY-3-8912 sound chip, a variant from the same 8910 family found in the MSX, Amstrad CPC, later model Spectrums, and Atari ST. Oric computers had a large built-in speaker and even had three sound effects available in BASIC: simply typing SHOOT, EXPLODE, or ZAP plays a sound.

» The keyboard is the Oric-1's major weak point, featuring atrocious rubber keys that even Spectrum owners would find horrible. Storage was limited to cassette.

» Deciding on a launch date is difficult. The Oric-1 was announced to the public in September 1982 but didn't really start shipping until early 1983.

» Early advertisements promised a 16KB version for around £100 ($123, or around $515 in today's money), a 32KB version for £140 ($172), and a 48KB version for £170 ($210). However, after manufacturing issues, Tangerine dropped the 32KB model and raised the 16KB model's price to £130 ($160) —just as the price of rival Sinclair's 16KB Spectrum had been cut to £100 ($123).

2 ORIC ATMOS

In February 1984, Tangerine developed the Oric Atmos: an evolutionary update over the original Oric-1. The 6502 CPU was now a newer 6502A and there was an updated system ROM, which fixed numerous bugs but caused errors with some Oric-1 software. However, the main update was the keyboard: gone were the nasty rubber keys in favor of proper plastic keys in a striking black and red color scheme.

» Along with the release of the Atmos, there was also a modem, printer, and floppy drive that were promised with the launch of the Oric-1. Multiple third-party products were launched but Oric's own Micro Disc drive read three-inch disks with 160KB of storage on each side.

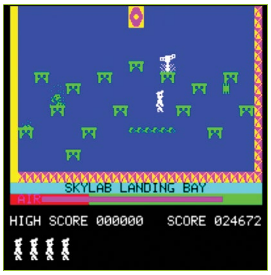
3 SOFTWARE

The Oric library wasn't nearly as extensive as those of its rivals. Although there are some educational and business titles, the bulk of Oric software is games. The library is split between British and French titles, with most early software being British and most later software French.

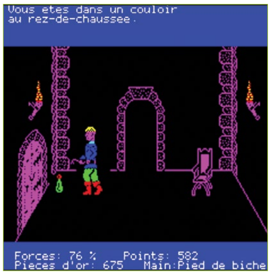
» Graphically, the Orics feel like a cross between a BBC Micro and ZX Spectrum, with the colors and chunkiness of the Beeb and the color clash of the Speccy, albeit to a lesser degree. As floppy drives were twice the price of the actual computer, disk software isn't as common as tape.

» We will try to limit our software picks to English language titles, although quirky chicken-centric arcade title *Cock 'In* (1984) is a favorite on both sides of the channel. For anyone looking for a multiplayer party game, *Don't Press The Letter Q* (1984) provides a neat collection of clone games for up to nine players. *Krillys* (1984) is a great clone of arcade bomber *Scramble*, while *Lone Raider* (1983) appears to be a *Scramble* clone at first, then turns into a multi-genre shoot-'em-up.

» For more modern titles, *Toxic Slime Considered Harmful* (1995) and *Zip and Zap* (1998) provide interesting arcade puzzle action. But for games from this century, nothing beats the prolific output of Anglo-French software team, Defence Force. Of its many releases, the most notable ones are a port of *Impossible Mission* (2010), the enhanced *Elite* port, *1337* (2010), and the excellent point-and-click adventure, *Blake's 7* (2017).



» *Manic Miner* (1985) has even worse graphics than the Spectrum original but packs in 12 extra screens.



Vous etes dans un couloir
au rez-de-chaussee.

Forces: 76 % Points: 582
Pieces d'or: 675 Main:Pied de biche

» *L'Aigle d'Or* (1984) is a highly-revered Oric classic game. Sadly, it is only available in French.

© BUG-BYTE SOFTWARE LTD, LORICIELS

» Both these computers are essentially the same, but hardware aside, you have to admit, Oric's designers had a sense of style.

© "ORIC-1 AND ORIC ATMOS" BY MARCIN WICHARY IS LICENSED UNDER CC BY 2.0.

SPECIFICATIONS

ORIC-1 & ORIC ATMOS (1982, 1984)

CPU:	MOS Technology 6502 @ 1MHz
RAM:	16KB or 48KB
Launch price:	$160 (approx)
Graphics:	240 x 200 resolution, 8 colors
Sound:	General Instrument AY-3-8912
Storage:	Cassette, 3-inch floppy
OS:	Oric Extended BASIC, Sedoric
Released:	September 1982, February 1984
Production:	1982 to 1987
Worldwide sales:	210,000 (Oric-1), 120,000 (Atmos)

» To find Oric software, archive.org has a decent collection, but for something more tailor-made, head to www.oric.org. They have an extensive library full of information, though you will need to create an account to download software.

4 LEGACY

The Oric-1 got off to a decent start. The system was generally well-reviewed and even won a Best Home Computer award in France, where its RGB output worked well with SECAM televisions.

» The Oric-1 occasionally outsold its British rivals but ultimately never approached the final sales of its Sinclair rival. Early production issues and problems with software distribution started to annoy the British press and customers alike. Outside cash injections helped bolster Oric's software library and support, but a suspected case of arson destroyed the Oric factory, bringing the business to its knees.

» Oric was soon bought out by Edenspring Investments, then moved quarters to Cambridge. The new arrangement survived long enough to develop the improved Oric Atmos. Nevertheless, British operations were suffering cash flow problems, getting bogged down in legal wranglings, and competing machines were beating the Oric on price and features.

» Life was better in France, however, where the brand was growing in popularity and sales. When Oric went into receivership in the UK, it was bought out by French company Eureka. Eureka carried on with the Oric Stratos, a 64KB updated machine; the Atmos 2, a Minitel microserver; and developed the Telestrat, also 64KB, with a focus on expansion and an internal modem.

» However, the French market would soon come to be dominated by the Amstrad CPC. The Telestrat only sold around 6,000 units and production of the Atmos stopped in March 1987. The Atmos design was licensed to make clones in Yugoslavia, where it was sold as the Nova 64, and Bulgaria, under the name Pravtez 8D.

5 EMULATION

Emulating the Oric is refreshingly straightforward. The emulator we will be using is Oricutron. Downloads are available at author Peter Gordon's website, with versions for Windows, Mac OS, and a number of niche operating systems. Although the documentation recommends grabbing certain ROM files from the project's GitHub page, we found everything seemed to run fine without them.

» Curiously, a binary for Linux isn't provided. We did find an old Fedora package online, and adventurous users may try compiling from source, but this is one program that is crying out for Flatpak or AppImage. We just cheated and ran the win32 version through Wine.

» Download the Windows Zip file, extract the contents, and open the folder in your file browser. Inside the main folder will be the program executable, oricutron.exe.

» Once loaded, Oricutron will boot to a BASIC prompt.

6 LOADING DISKS AND TAPES

Loading software through Oricutron is easy. We'll start with the hardest option first: tapes.

» Open the main menu, either by right-clicking on it or pressing F1. Choose 'Insert tape' from the menu and that will open a file browser. Select your tape image and click Open.

» Oricutron will now drop back to the BASIC prompt. Enter the following command, noting the two double-quotes:

```
CLOAD""
```

» Your program should now load, and surprisingly quickly.

» To load disk images, open the main menu again and choose 'Insert disk 0'.

» The majority of disks should load automatically. If you're finished using disks and want to remove your disk without closing the emulator, you will have to do so via a sub-menu. Open the main menu, choose 'Hardware options', and select 'No disk'.

7 GOING FURTHER

The over-reliance on menus is one area where Oricutron could do with improvement. For instance, to enter fullscreen, you have to choose 'Video Options' from the main menu, then select Fullscreen.

» To reset the machine, you can press F4, but this often messes up the audio, so you're better off selecting Reset from the main menu. However, it is worth remembering the F6 key, which toggles warp speed mode.

» For some final notes, it's worth copying any disk or tape files into the "disks" and "tapes" folders within the main Oricutron folder. Oricutron will open to these folders automatically when you load a tape or disk, and some games and demos are already provided.

» Some disks will display a message saying, 'Warning—DOS is altered!' These require the use of Sedoric, a weird kind of DOS for Oric computers. We don't have space to cover Sedoric here, but you can find instructions at http://oric.free.fr/DISKS/sedoric.html.

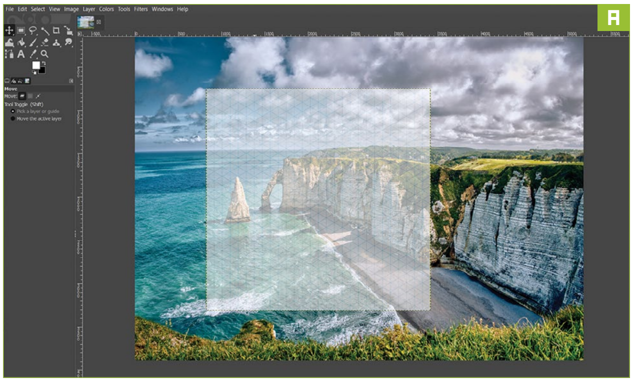
3D map effect with GIMP

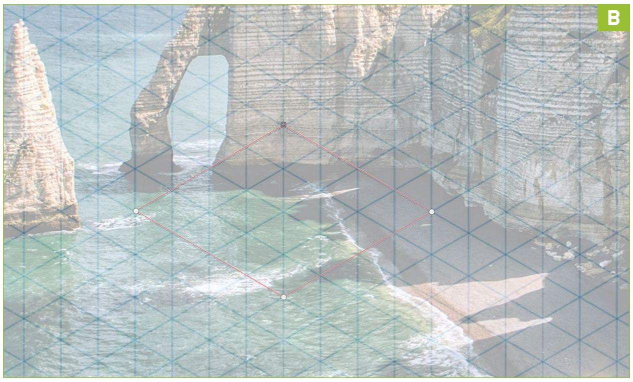
YOU'LL NEED THIS

GIMP 2.1
OS: Windows 7 or newer

WHEN USING A PHOTO MANIPULATION application such as Adobe Photoshop or GIMP, there are many more possibilities than you may initially realize. Plenty of these programs can be used in various ways to create unique pieces of artwork. In this tutorial, we will create isometric 3D art using GIMP. This technique can be transferred onto all sorts of different media and can be used to emphasize a particular place or subject. Learning as many skills as possible can enable you to broaden your creativity by applying them to new forms.

We will be using an image from Unsplash, which is of a skewed piece of land, taken from an angle and not a birdseye view. This will help later on in the tutorial to create a 3D effect. In particular, we've chosen an image of the coastline at Étretat in France by Allyson Beaucourt and we will use part of this image to create our isometric cutout. Of course, you can use any image you like, as long as you have the license for it. Unsplash and other license-free image sites are great for practicing and getting to grips with these skills. **–SAM LEWIS**





1 WORKING OFF-GRID

Once you're happy with your image, open it up in GIMP, either through the file selection method, copy and paste, drag or drop, or right-clicking on the image and opening with GIMP. Yep, there are plenty of different ways to get started.

» After this, rename the image to suit your work, duplicate this unchanged image and then lock and hide that layer. It's always important to have a spare duplicate in case we need to go back and make some changes.

» Next, we need to download an isometric grid from an image browser to use to draw our cutout shape. Once it's been downloaded, head to File, Open as layer and then click the file. Bring this over your image and reduce the opacity so that you can see your original through the isometric grid. This is now where we will choose the section we want to emphasize. [**Image A**]

2 TAKE THE RIGHT PATH

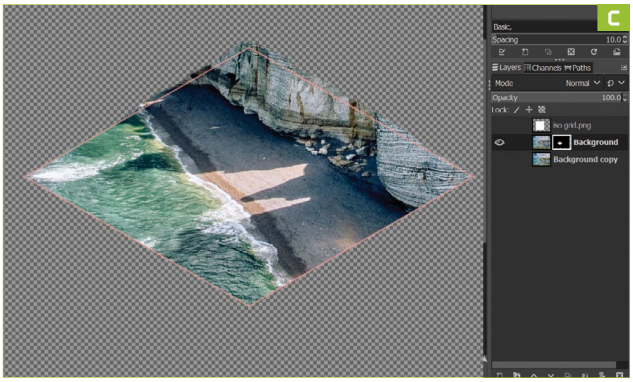
So you've decided where you want to cut, now we need to use the pen tool to draw this shape. Create an equal isometric square similar to the one we've created in our example using this grid as a guide to follow. Make sure the isometric grid layer is locked and that you have the main background layer selected [**Image B**].

» To create this, use the paths tool on the left-hand side of GIMP's default workspace. Click over the isometric grid to create a shape as we have. To close your path, hold CTRL and click once you've finished.

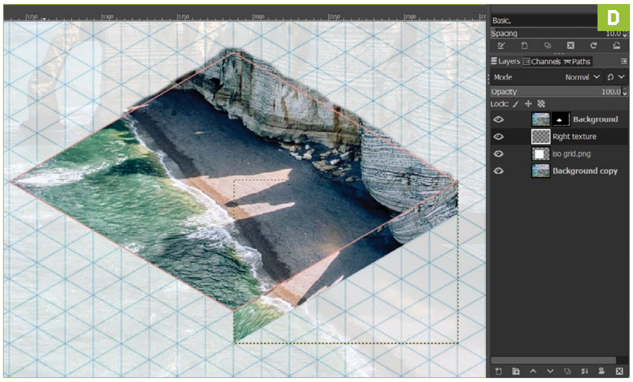
» Next, head to the paths panel, which is next to the layers panel, and select the eye icon to see this path. We can then go back to the Layer panel and use the move tool to fine-tune the part of the image you wish to emphasize using the 3D effect. Drag the image along until you're happy with what is in your created shape.

3 ADD SOME TEXTURE

Once the placement has been chosen, we need to once again return to the paths panel and right-click on the path. From the pop-up window, choose 'path to selection' and then hide this path layer and go back to



© GIMP



Basic,
Spacing 10.0
Layers | Channels | Paths
Mode Normal
Opacity 100.0
Lock:
Background
Right texture
iso grid.png
Background copy

the standard layers. On your main layer, right-click and select 'Add layer mask'. This will open another panel—in here, choose 'Selection' and then click add.

» After this, hide the dotted lines by going into the Select menu at the top and choosing 'none'. We can then hide all the remaining layers other than the main layer which we have just cut our isometric shape from [**Image C**].

» Here, we want to give both the top left and top right-hand sides of the shape a texture. To do this, select the mask thumbnail in the icon, and using the brush tool with the white color selected, we can draw a rough edge to these sides of the shape. This will give a natural edge to our 3D shape.

4

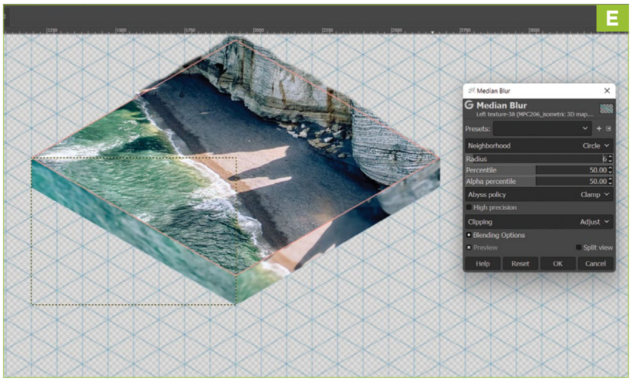
3D, OR NOT 3D

Now we have the majority of the shape done, we can start to add the 3D sides of the shape. We need to use texture from the existing image to create this and the isometric grid once more. Using the original duplicate layer, we take some of the sand and rock from that layer to form a new layer.

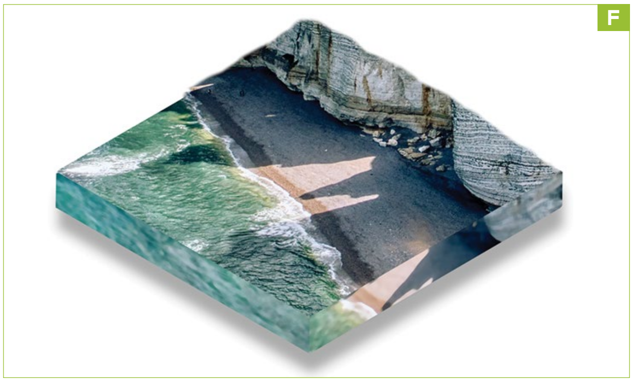
» Make sure you have the rectangle tool selected, draw a rectangle that covers both of these textures, and then copy and paste this. It will create a pasted layer. Again, when creating new layers, name these accordingly to your document. We're aiming to take a snippet that can match the side of the 3D shape we already have like in our example [**Image D**].

» After that, make sure the isometric grid layer, the original image, and the new texture layer are visible. Bring the isometric image to the bottom and then select the texture layer. In the transform tools, select the perspective tool and morph it to create one of the sides to the 3D isometric image as shown.

» Now apply the same method to the other side of the shape. On this side, we only have some of the sea visible so we are just going to use a crop from the sea to create this edge making life a little easier.



Median Blur
Left texture-38 (MPC206_isometric 3D map....
Presets:
Neighborhood Circle
Radius 6
Percentile 50.00
Alpha percentile 50.00
Abyss policy Clamp
☐ High precision
Clipping Adjust
Blending Options
☒ Preview ☐ Split view
Help Reset OK Cancel



5

IT'S ALL A BLUR

Now, add a median blur to the right and left texture edge layers. Head to filters, then blur, and median blur when selecting a layer. Every image will need different levels of blur, so play with the toggles until you're happy. Now, let's add a shadow. [**Image E**]

» In the layer panel, have the layers you want visible, then right-click on any active layer and select 'new from visible'. This will create a new layer from all the viewable layers on your panel.

» Make sure this layer is active, go to filters, light, and shadow, and select 'drop shadow legacy'. Set the X offset to 5, the Y offset to 60, and the blur radius to 50. Also, make sure the color is black, opacity is 60, and that the 'allow resizing' box is unchecked, then hit OK [**Image F**]. This will create a blur around the image.

» Finally, create a white background layer and bring this all the way to the bottom with only this and the new visible layer selected... and we're done!

GIMP PLUGINS

GIMP
vs
PHOTOSHOP
CROPPING
IMAGE
Remove Image Background
GIMP
photo editor
ALTERNATIVES

GIMPTUTORIALS
HOME LEARN COMPARE ALTERNATIVES BLOG ABOUT US
Featured
GIMP vs Photoshop
Photoshop is the only image editor in history to have its name turned into a verb: 'to Photoshop' a picture means to edit it. GIMP doesn't exactly enjoy the same ...
Read More
How to Crop an Image in GIMP
How to Remove Background in GIMP
7 Best GIMP Alternatives in 2022

By default, GIMP has a decent selection of tools, brushes, and textures available but this can always be improved. Plugins are a great way of boosting your arsenal and your creativity, giving you more tools to play around with. A quick Google search will give you a huge variety of different plugins to try. If you're thinking of a tool that you may need, it probably already exists, so it's worth researching before getting deep into a new project—these plugins can improve your workflow and save precious time designing. A good place to start is by heading to thegimptutorials.com. Here, you can learn more information about plugins, how to install them, and examples of great plugins to try out.

BUILD IT

SAM LEWIS, STAFF WRITER

AMD's refreshed mid-tier machine

Is the new Radeon RX 6650 XT worth adding to your rig?

LENGTH OF TIME: **2-3 HOURS**

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

IF WE HAD TO NAME our favorite aspects of PC building, it'd be the individuality, craftsmanship, and customization that come naturally when creating your own computer. Although you may start out with a rough idea of the PC you'd like to build, there are plenty of variables during the process that mean it doesn't always go to plan. There are almost infinite combinations of kit to select from, but budget, availability, compatibility, and component clearance can rip up the ideal build with no regard for your emotions.

A good way to start a build is to think about futureproofing. If you can't get hold of everything at once, you can always swap out components down the line and there are parts of a machine that you can save some money on initially.

One of the key parts we've saved money on initially is our Phanteks P400A case—a universal and budget-friendly case that supports ATX, Micro ATX, Mini ITX motherboards, and even E-ATX (up to 272mm wide). With plenty of space, fan capacity, cable management solutions, and a simplistic black design, it should pair well in most environments and house a wide variety of builds. Sure, the beauty of custom PCs is that this can be swapped out down the line but, for now, it's a reliable enough case.

What we're aiming for is a rig that is good enough to game on from the get-go, but with room for improvement down the line. We have a powerful CPU and one of the latest Radeon budget to mid-tier GPUs to test out, both by AMD. Hopefully, in our conclusion, we'll find out whether this is a good starting point for this rig.

msi
PHANTEKS

THE INGREDIENTS

WE'VE ALREADY MENTIONED the chassis for this build, but what about the components within? The AMD Ryzen 9 3900X CPU should be futureproofed, regardless of the incoming AM5 socket. With 12 cores, 24 threads, and a clock speed of 3.8GHz, it's a dependable and powerful chip. Alongside this, we have AMD's Radeon 6650 XT—specifically, an MSI Radeon RX 6650 XT Gaming X 8G, which comes with 8GB of GDDR6, PCI Express Gen 4 x8, and a memory speed of 17.5 Gbps. This revamped budget GPU should provide a solid gaming experience.

As for the other components, we have a two-stick 8GB Corsair Vengeance RAM kit running at 3200MHz, which is plenty to keep your machine running up to speed. For most work and gaming purposes, 8GB of RAM is still a decent amount and, of course, it can be upgraded down the line. We also have a WD Black SN750 SSD—a great low-end SSD to get started with, although, again, there is room for improvement moving forward.

Another good starting point is our CPU cooler. Noctua's NH-U12A is a strong-performing sub-$100 radiator. We will channel the airflow to go through the CPU cooler to help in this department. All of this is sitting on an Asus TUF GAMING B550M-Plus (WIFI) mobo. With a micro-ATX form, it leaves plenty of room to work around inside this Phanteks P400A case. It has an AM4 socket, PCIe 4.0, dual M.2, and WiFi 6.0, a great package for a little over $150.

Last but not least, we have an NZXT C750W power supply to keep things ticking along. Now, let's piece this thing together and see if it's a good starting point for a mid-tier machine.

INGREDIENTS

PART		STREET PRICE
Case	Phanteks Eclipse P400A	$110
Motherboard	ASUS TUF GAMING B550M-PLUS (WI-FI)	$162
CPU	AMD Ryzen 9 3900X	$400
CPU Cooler	Noctua NH-U12A	$120
Memory	8GB (2x 4GB) Corsair Vengeance LPX DDR4-3200	$90
GPU	MSI Radeon RX 6650 XT GAMING X 8G	$450
SSD	1TB WD Black SN750 NVMe 2.0 SSD	$140
PSU	NZXT C750 80+ Gold PSU	$89
OS	Windows 11 Home 64-bit	$20
Total		**$1,581**

1

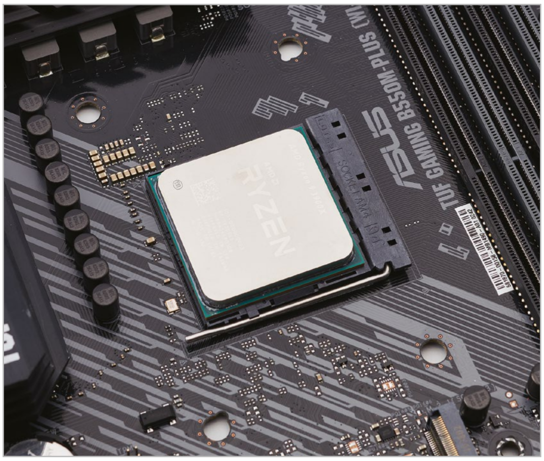
BACK TO BASICS

LEAVING YOURSELF as much space as possible is a top tip for PC building. It can get tight inside the case, so always try to take as much out of it as you possibly can. This Phanteks Eclipse P400A case has four thumbscrews holding in the tinted tempered glass front panel. Loosen these and gently lift off the glass, putting it aside somewhere safe. Also, work with the case flat on a surface so it doesn't slip. Similarly, the back panel slides out with two rear-facing thumbscrews and the front panel also pops off easily from the bottom. We also aligned the two 120mm case fans so that they will pull air through the case and over where the CPU will be. These fans are facing forward—remember, faces suck air.

2

THE CPU BEHIND THE WHEEL

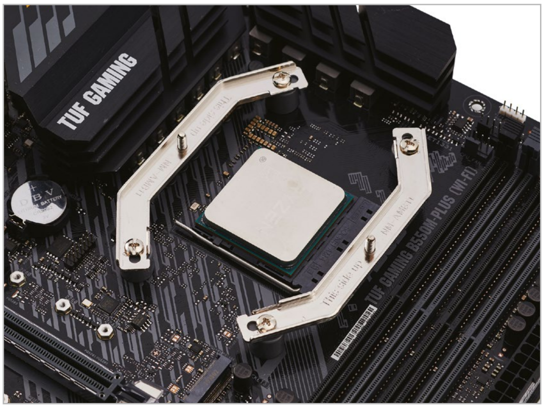
MOVING AWAY from the case, our next stage is to add the Ryzen 9 3900X to our motherboard. We take the board and lay it down on the protective static shielding wrapper it came with. Then, we gently lift the retention bar, which slides the AM4 socket slightly, and grabbing the sides of the CPU, rest it down, making sure not to touch the pins. Make sure the arrow on the CPU aligns with the arrow on the motherboard. Pulling the retention arm back into place will secure the CPU. Don't be alarmed if the branding on the CPU isn't horizontal—as long as the arrows match up, you're good to go.



3

BRAIN BRACKET

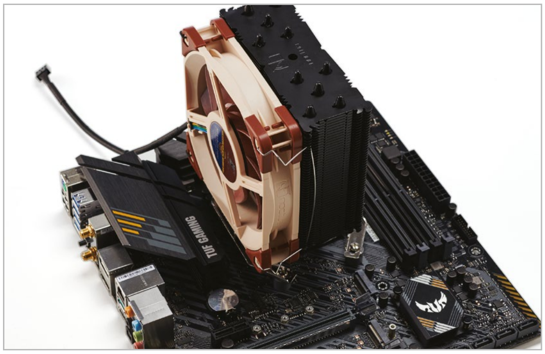
BEFORE we add the CPU cooler, it needs somewhere to sit. First, take the motherboard's AM4 CPU backplate and place it on the back of the mobo, making sure it aligns with the screw holes. Then, using the grey AM4 plastic spacers in the Noctua box, place one of these on each corner. Next, take the appropriate mounting bars and rest them on top of the spacers, making sure they line up with the AM4 holes. Once that's done, take the four remaining screws from the Noctua kit and screw the bracket together through the motherboard and into the backplate. Our Noctua NH-U12A comes with everything you'll need to get this bracket installed.



4

KEEPING A COOL HEAD

IT'S BEEN a while since we used a cooling system like this, but we thought we remembered how to attach the Noctua fan to the cooler. However, it soon became apparent that you can't access the screws to fasten the cooler onto the bracket with the fans attached. After being humbled by a CPU cooler, we tightened it in place and then reattached the fan via the wire clips, making sure the faces went the same way as the case fans. These fan clips can be a nightmare to get on and require some patience. We actually managed to lose a clip in the process, which resulted in only being able to use one of the two 120mm fans provided. On the other hand, this shouldn't affect cooling much as we are already channeling the air through this path via the case fans.



7

THE MOTOR MEETS THE CHASSIS

WE'RE ALMOST done with the motherboard, but before we add our graphics card, we need to install the mobo into our case. First, we installed the I/O shield into the back of the case and then laid it flat. Gently holding the edges of the board, we rested it down into place. As this is a Micro ATX board, some of the standoffs at the bottom had to be moved upwards to line up with our motherboard screw holes. We secure it down into place using a skinny magnetic screwdriver, which certainly helps when getting into those tight places where losing a screw is almost as bad as losing your Runes in *Elden Ring*. We've been there, done that, and we're not proud.

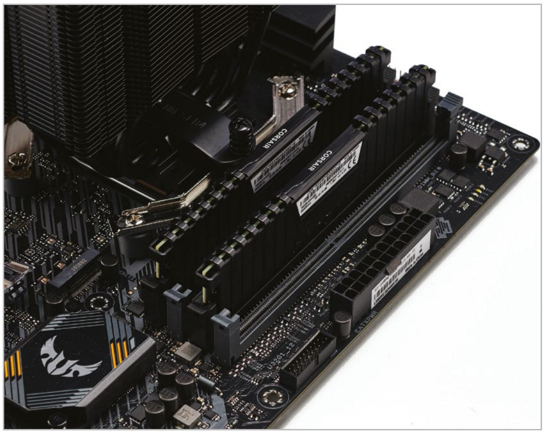
8

SECURING THE POWER

A PC WITHOUT a power supply is like gaming on a trackpad, rather tricky and pointless. Thankfully these are easy to install. We place the PSU in the bottom at the back of the PC with the fan facing downward and, using four screws, attached this to the case. Our holes didn't align perfectly so we had to almost force the issue, but thankfully we managed to tighten the screws. To make more room, we took out the HDD cage underneath, which will make it easier to attach all of our PSU cables.

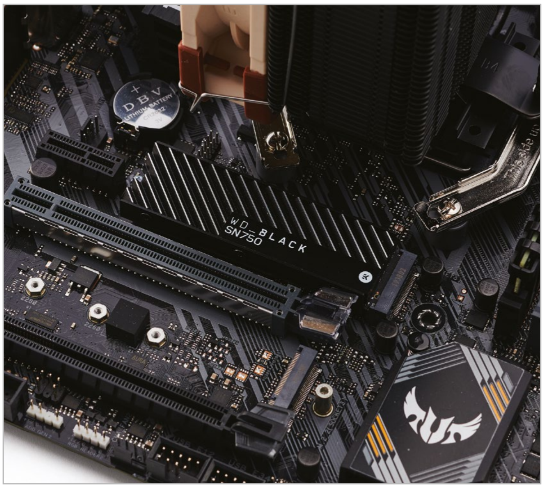
5 DON'T RAM IN THE RAM

LOSING THE FAN CLIP has the benefit of giving us more room to the right of the cooler. This makes it easier to get to our RAM, both for installing and also if we need to update this down the line. We need to install our two sticks in the first and third DIMM slots, but you should always refer back to the motherboards manual when not installing a full amount of RAM. On this mobo, you don't need to unclip both sides, just the clips towards the top. Once these are open, align the notch of the RAM sticks with the line in the slot and pop it carefully in. It should click into place, closing the clip in the process.



6 MEMORY LOG

OUR WESTERN DIGITAL Black SN750 comes with a heatsink which is good news as it means we don't have to mess around with a motherboard one. Using the most upper M.2 slot on your board, we take the SSD and slide it into the port at a 30° angle. Then, we rest it down and line it up with the spacer on the board. Take the tiny motherboard SSD screw and fasten it in place to secure the SSD down—be very careful not to lose it, as you could spend the rest of your day trying to retrieve it.



9 THE PARTY PIECE

JUST BEFORE we install our GPU, we need to take out two PCIe shields from the case, specifically shields 2 and 3. This differs from case to case but as we are using the top PCIe slot on the motherboard, these are the shields that line up with it. There is a cover on the top of the screws that will first need to come off—simply loosen the screws on the shield and slide it out. Once you've made room, open the clip on the PCIe slot and gently push the GPU into place. The shield on the GPU should line up with the slot on the case and then you can use the screws from earlier to secure this down. The GPU will also click into place, much like the RAM installation.

10 POWER CABLES

IN THE SAME way that not having a PSU would make a PC useless, you also need the cables to connect everything together. We always start off with the most frustrating cable, the CPU cable, which typically sits at the top left of the motherboard. Getting this in and feeding the cable out through the back can be a nightmare but, remember, patience is a virtue. The rest of the cables are significantly easier, our GPU only has one PCIe port at the front so there's less cable mess. Taking out the HDD cage makes it a breeze to attach them to the back of the PSU.

11

CASE CABLES

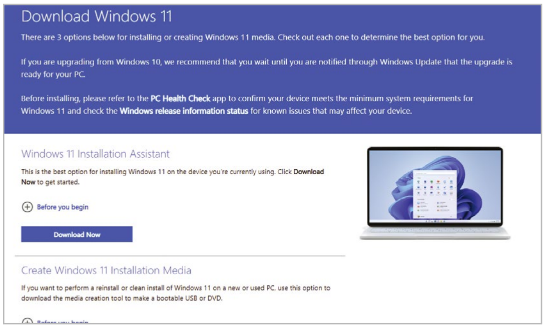
SLIGHTLY MORE difficult than the PSU cables are the last remaining case cables. As the power cables from the front I/O panel were single and not connected to one connector, we had to refer to the motherboard's manual to make sure we were on track. These tiny cables connected to a pin each and were extremely fiddly but we managed to get them connected to the correct pins regardless. Other than that, the rest of them were straightforward. While connecting the cables, try to cable manage as you go by putting loose cable ties on. Then, once you think you've finished, see if the PC springs to life by plugging it in—if it does, you can go ahead and tighten the cable ties. Thankfully ours started up, so after a little cable management, we proceed to the software side of things.

msi
ATX
MICRO ATX

12

FROM HARDWARE TO SOFTWARE

WHEN BOOTING a fresh PC, you need another one handy from which you can get Windows and grab an update for the BIOS. If your PC boots up to the BIOS, you can create a Windows 11 install by heading to Microsoft's media creation tool, downloading Win11, and following the on-screen installation wizard—you will also need an 8GB formatted USB. Insert the USB into the new build and change the boot priority in the BIOS, making the USB stick the main boot. Restart the computer and the Windows 11 installation process should begin. If not, head to the manufacturer's web page for your motherboard and download the latest BIOS update onto a clean USB drive. On the motherboard's I/O shield, insert the drive into the 'BIOS FLBK' port. Then refer to the mobo's instructions on how to flash install the BIOS update.



Download Windows 11

There are 3 options below for installing or creating Windows 11 media. Check out each one to determine the best option for you.

If you are upgrading from Windows 10, we recommend that you wait until you are notified through Windows Update that the upgrade is ready for your PC.

Before installing, please refer to the **PC Health Check** app to confirm your device meets the minimum system requirements for Windows 11 and check the **Windows release information status** for known issues that may affect your device.

Windows 11 Installation Assistant

This is the best option for installing Windows 11 on the device you're currently using. Click **Download Now** to get started.

Create Windows 11 Installation Media

If you want to perform a reinstall or clean install of Windows 11 on a new or used PC, use this option to download the media creation tool to make a bootable USB or DVD.

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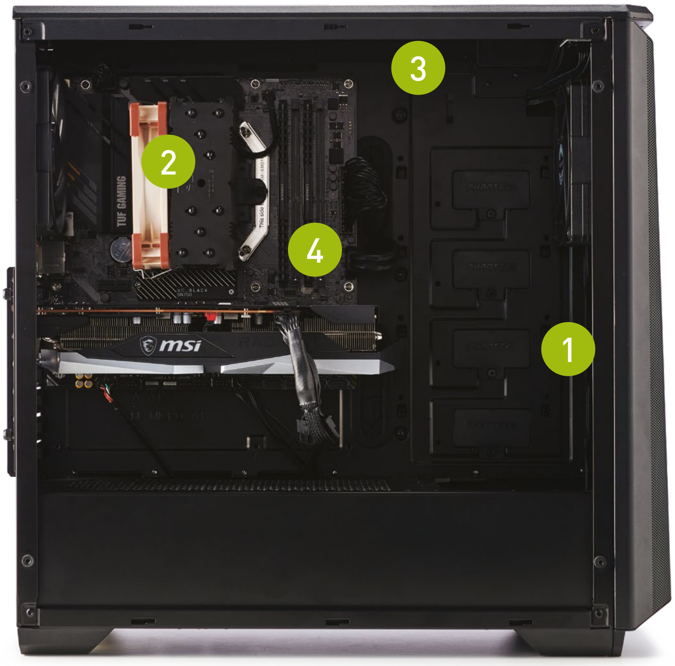


1 Using a Micro ATX mobo gives us plenty of space to add an AIO cooler in the future.

2 We used the standard brown color Noctua NF-A12x25 fan to stand out, but we should have stuck with the chromax.black fans to suit the build better.

3 Some RGB fans along the top would give this interior a little more pizzazz.

4 A full kit of RAM would also go down a treat to make this a cleaner looking build and give added performance.

THE CONCLUSION

OUR AMD MID-TIER build has come to an end but its digital life has only just begun. Apart from hunting around the studio for a fan clip for what seemed like an eternity, this build was fairly straightforward. Cable management can feel like a burden at the end of a build, but putting in that extra effort to tidy up your cables takes your system to the next level. Why go through the effort of making a custom PC if you're going to leave a heap of spaghetti at the bottom of the case?

We will be benchmarking this PC against our new 1080p build, even though the street value of our build is around $400 more than the 1080p build. However, some components in this mid-tier build offer greater futureproofing potential, such as the AMD Ryzen 9 3900X, making this machine more viable in the long run. This chip is currently sitting at a high price, so if you can't pick one up for cheaper than the current street price, we'd recommend holding off until you can. Although this CPU has plenty of life left in it and is a great chip to control your rig, it has a high core/thread count (12/24) and is a solid performer for gaming.

Paired with it is our new MSI Radeon RX 6650 XT Gaming X 8G GPU. Compared with the XFX Speedster QICK 308 AMD Radeon RX 6600 XT, our GPU is a refreshed version offering around an increase of five percent performance. Not bad considering our GPU is cheaper than the street price of the one used in the 1080p benchmarking build. We enabled AMD Smart Access Memory, which can be used if you have either an AMD 5000 Series or select 3000 Series processor with an AMD Radeon RX 6000 Series GPU.

If you have compatible components, head to your system's BIOS, go into advanced settings, and then enable "Above 4G Decoding" and "Re-Size BAR Support".

When it came to benchmarking the games, we had a frame rate increase of 13 percent on *Total War: Three Kingdoms*, a 12 percent increase on *Cyberpunk 2077*, and a 17 percent increase on *Cyberpunk 2077* with RTX ray-tracing enabled. Sure, our setup is more expensive but with a similar GPU, this is quite a good increase.

Where we fell behind the 1080p build was on *Metro Exodus Enhanced Edition*, both on the regular benching and RTX ray-tracing but only by small margins. The rest of the build stood up strong too with faster read and write scores and also a higher multi-core figure in Cinebench R23. We are impressed with the PC's performance and for an added bonus, it runs nice and quiet too. For a mid-tier build, it's a great starting point if you want a setup to customize down the line but is still more than usable in ultra settings on triple-A titles. ⏻

BENCHMARKS COMPARISON

	ZERO-POINT	
Cinebench R23 Single-Core (Index)	1,537	1,275 (-17%)
Cinebench R23 Multi-Core (Index)	10,632	16,718 (57%)
CrystalDisk QD32 Sequential Read (MB/s)	3,287	34,36 (5%)
CrystalDisk QD32 Sequential Write (MB/s)	2,419	2,992 (24%)
3DMark Fire Strike (Index)	24,814	23,894 (-4%)
Cyberpunk 2077 (fps)	68	76 (12%)
Cyberpunk 2077 RTX (fps)	18	21 (17%)
Metro Exodus (fps)	75	73 (-3%)
Metro Exodus RTX (fps)	52	47 (-10%)
Total War: Three Kingdoms (fps)	72	81 (13%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our 1080p zero-point consists of an AMD Ryzen 5 5600X, an XFX Speedster QICK308 Radeon RX 6600 XT, an Asus ROG Strix B550-F WiFi, 16GB of XPG Gammix D45 DDR4-3200, and a 1TB ADATA Legend 840. All games tested at 1080p 'Ultra' graphics presets with DLSS/FSR and V-sync turned off. XMP/AMP for RAM speed turned on in all tests. No manual CPU overclocking.

LAB NOTES

SAM LEWIS, STAFF WRITER

Playdate

Netflix meets handheld retro gaming?

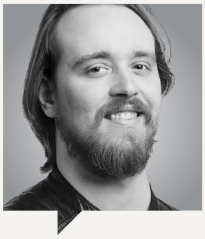
NETFLIX AND RETRO GAMING? It's an intriguing-sounding combination—and it's not too far from the truth. Meet the Playdate, a fun and modern take on the retro handheld games console. It's pretty clear that this latest addition to the handheld gaming scene has taken its design cues from the Nintendo Gameboy, but it also looks like a squashed and more pocketable version of the Analog Pocket.

However, the Playdate offers something different from those two consoles in that you won't be able to natively play your favorite retro game titles on it. The games available on this console will be new and limited to the Playdate. As minimal as the design looks, this little handheld has some fairly modern features—though before you get too excited, that crank handle is not for charging the device, it's a cool input control.

So how does this tie in with Netflix? You can't stream the latest season of *Stranger Things* on the Playdate and, with its 400x240 1-bit screen, you wouldn't want to. However, the games on this device work on a seasonal basis—much like Netflix, you won't always know what is coming out. With the Playdate, you get free access to season one, which includes 24 different games, released at the rate of two per week for 12 weeks. These are transferred onto the Playdate via Wi-Fi.

This concept is certainly an interesting take on subscription-based gaming, bringing the anticipation of what games you'll get from Xbox Game Pass and similar services, and mixing it in with the nostalgic handheld retro gaming we are all accustomed to. While it should be an interesting product, it does come with a rather hefty pre-order price tag of $179.

Portable gaming with a subscription fee?



CHRISTIAN GUYTON

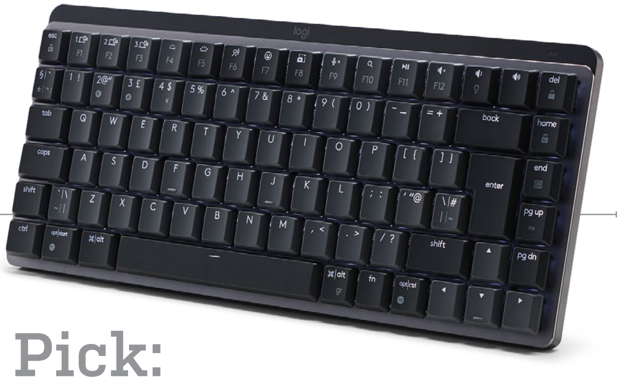
Staff writer

Skip ahead a few pages, and you'll find my review of Teenage Engineering's first PC case, the computer-1, a mini-ITX chassis. I won't spoil the details of the review but the Swedish manufacturer has produced a flat-packed, build-your-own case, using bendable aluminum panels and a whole lot of screws to hold it all together.

Regardless of the quality of the finished product, I wanted to say how much I enjoyed building in the computer-1. It has the same blend of confusion, action, and satisfaction that comes with assembling a chest of drawers or a TV stand, right down to the step-by-step instructions and the alphabetical tags assigned to each tiny component.

Teenage Engineering's designers understand the most important thing about building PCs. It should be fun! Every screw secured, every panel set in place, should bring that tiny rush of dopamine that culminates in the joy of a completed build. Even the manual appreciates this; it implores you to 'rip apart!' the banded front I/O cable, and advises 'think twice, bend once!' when flexing the panels.

I hope more manufacturers take a leaf out of Teenage Engineering's book. Some cases don't have that little bit of magic that makes building a system inside them enjoyable, and they could learn a thing or two from the humble computer-1.



Editor's Pick: Logitech MX Mechanical Mini Keyboard

Mechanical keyboards: not just for gamers

THERE'S A quiet revolution happening in the productivity space. Well, I say quiet—it's actually the click-clack of mechanical keyboards making their way back into the offices that they left 30-or-so years ago. At least that's the plan according to Razer and now Logitech, who have both recently released work-based takes on the mechanical keyboard.

Both keyboards are available in either Linear or Silent switch types, although Logitech does also sell the noisier clicky variety (confession: I'm the annoying guy in the office who prefers the louder switches). I received the 'Tactile Quiet' variant of the MX Mechanical Mini, meaning Cherry MX Brown equivalent switches on a compact frame that loses the numkeys and rearranges the navigation keys vertically on the right to save even more space.

At $149 for this Mini version and $169 for the full size, there are many wireless keyboards out there for a lot less money, including Logitech's own non-mechanical MX Mini for $99. What you're paying for is the mechanical feel and robustness that comes with it. That means not just the satisfying feeling of typing and the practically infinite life you'd expect from a mechanical board, but also an aluminum top case that feels backpack-proof.

The keyboard also has lots of features to justify the price, including fully customizable function keys through Logitech's software and an ambient light sensor that senses when your hands are close and illuminates the keyboard accordingly. That illumination is also fully customizable in Logi's software in the same way as a lot of gaming keyboards, only thankfully without all the RGB effects.

It's also worth mentioning the huge battery life of this thing—15 days with the keys illuminated or 10 months without. You can also get a full day's charge with a 15-minute top-up over the USB-C connection. If you're at a desk all day, you can also just leave the thing connected and that way you don't have to worry about it.

The wireless features of the MX Mechanical are excellent—the keyboard can pair up using the included Logi Bolt receiver or Bluetooth, and you can switch between machines seamlessly using the function keys. If you're moving between Mac and PC, there are both Start and Option keys available for navigating both operating systems. One minor niggle is that there's nowhere on the board to store the wireless dongle if you're traveling like there is on the underside of my Logitech G915 TKL gaming keyboard.

For me, the best part of this keyboard is that it has low-profile keys. I know that's a matter of taste, but as someone used to typing on laptops for the last 15 or so years, it's much more comfortable when I'm writing my articles. The dual-tone gray finish also helps distinguish between important keys on what is otherwise just an uninterrupted slab of keys.

It's also worth mentioning that both the keyboard chassis and packaging are made from recycled materials, and the keyboard is certified carbon neutral. As a gamer, I've become used to the smaller form factor of a TKL model, but the low premium for the full-size board means that's probably the board to go for if you're an office worker.

Ultimately, the Logitech MX Mechanical Mini is one of those premium upgrades that makes sense for people working across platforms who want a fantastic typing experience wherever they go. **–GC**

$150, www.logitech.com

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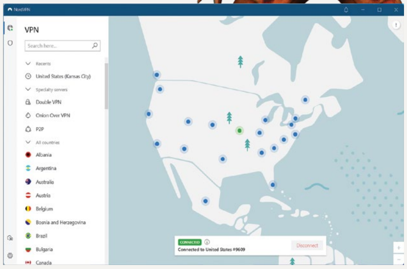

92 NordVPN vs. ExpressVPN

Asus RX 6750 XT ROG Strix

An incremental improvement worthy of the price?

AMD'S TRIFECTA of refreshed RDNA 2 GPUs continues with the Radeon RX 6750 XT, a minor update to the existing RX 6700 XT initially launched in March last year. Over a year later, the main update to AMD's Navi 22 offering consists of slightly boosted GPU clocks and power limits, coupled with 18Gbps GDDR6 memory. That all sounds fine, but what's not quite so welcome is the $70 jump in MSRP. Asus has also seen the ante and raised it another $100 for its ROG Strix model, which tacks on another 30W of power and a 43MHz overclock.

In terms of the numbers, relative to the reference 6700 XT, that means you get a 0.7 percent increase in GPU clocks, with 12.5 percent more memory bandwidth, 8.7 percent more power, and a 15 percent increase in price. Then Asus provides an additional 1.7 percent factory overclock and 12 percent more power, with an 18 percent bump in pricing.

On the surface, it's frankly questionable value, especially while GPU prices continue to drop—the cheapest competing Nvidia RTX 3070 card currently costs $600. Still, it's clear that pricing for AMD's GPU refresh has more to do with early 2022 than what we're seeing now, and we wouldn't be surprised to see retail pricing on the RX 6750 XT drop below $500 in the near future. That's assuming supply continues to outpace demand, which seems likely now that cryptocurrency mining profitability has taken a nosedive.

On paper, the combination of increased power limits and higher clock speeds should boost performance by up to 13 percent. In practice, even with the factory overclocked Strix card going up against a reference RX 6700 XT, the new GPU underwhelms, delivering a six percent overall improvement in fps, which was relatively consistent across our tested resolutions and settings. We saw between four to nine percent higher performance for our test suite, but most games landed around the six percent mark.

AMD ends up having to compete against both its existing RX 6700 XT, which will continue to be sold, as well as Nvidia's RTX 3060 Ti, RTX 3070, and RTX 3070 Ti. The RTX 3070 came out ahead in our overall metric, though that is skewed by the three ray-tracing games we included in our test suite. AMD falls well short of Nvidia in DXR (DirectX Raytracing) games, particularly those using more than a single RT effect. The RTX 3070 was typically around 50 percent faster in DXR games—and up to 90 percent faster in extreme cases such as *Minecraft*.

There's some good news in that AMD's FSR 2.0 (see *Tech Talk*, page 11) offers a competitive alternative to Nvidia's DLSS, though only a few games are available with FSR 2.0 so far. In contrast, Nvidia has over 200 games and applications that use DLSS and that number continues to grow every month. Considering that you can get better performance and features for roughly the same price—and even power consumption favors the RTX 3070—there's no compelling reason to opt for AMD's refreshed RX 6750 XT at this stage in the life cycle of the existing GPU architectures.

At least you get 12GB of memory, whereas Nvidia's 8GB feels quite stingy for a high-end card in 2022. But if you're hoping for a major upgrade in performance, you'll be better off sticking with whatever you're currently running and waiting for the next-generation architectures to arrive later this year.

As for the Strix card, it has a big and beefy cooler that did exceptionally well in our testing, typically keeping the GPU below 60°C while remaining very quiet—no surprise, as the same core design is used on higher tier RX 6800 XT class cards. There's also a decent amount of RGB lighting and dual VBIOS support. Those are nice extras, though we're still not convinced they're worth the price premium. **–JARRED WALTON**

BENCHMARKS

	RX 6750 XT	RX 6700 XT	RTX 3070 Ti	RTX 3070
10 Game Average	91 / 67	86 / 63	**99 / 77**	94 / 72
Borderlands 3	**129 / 88**	122 / 82	119 / 86	112 / 80
Control (DXR)	47 / 29	46 / 27	**76 / 49**	70 / 44
Cyberpunk 2077 (DXR)	26 / 16	25 / 15	**48 / 30**	45 / 27
Far Cry 6	**141** / 103	135 / 98	137 / **108**	134 / 101
Flight Simulator	84 / 61	81 / 57	**85 / 79**	86 / 74
Forza Horizon 5	**115 / 93**	107 / 88	105 / 90	104 / 89
Horizon Zero Dawn	**145** / 113	139 / 107	142 / **118**	135 / 109
Minecraft (DXR)	35 / 21	32 / 20	**68 / 43**	64 / 41
Red Dead Redemption 2	96 / 80	91 / 76	**107 / 89**	99 / 82
Watch Dogs Legion	92 / 69	86 / 65	**101 / 77**	96 / 73

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 1920x1080 / 2560x1440 ultra, with ray tracing enabled in Control, Cyberpunk, and Minecraft.

VERDICT 7

Asus RX 6750 XT ROG Strix

+ GIANT LEAPS 18Gbps GDDR6; plenty of memory; excellent cooling.

− BABY STEPS Barely faster than 6700 XT; struggles with DXR; questionable value.

$649 MSRP, www.asus.com

SPECIFICATIONS

Architecture	Navi 22
Lithography	TSMC N7
Boost Clock	2643MHz
GPU Cores	2560
Memory	12GB GDDR6
TFLOPS FP32	13.5
Bandwidth	432GBps
TDP	280W
Connectors	HDMI 2.1, 3x DisplayPort 1.4

The cooler on Asus's Strix card works well, but overall performance isn't that much faster than the RX 6700 XT.

Asus Zenbook Pro 14 Duo OLED

Two screens better than one?

DOES ANYBODY do laptop innovation like Asus? We sure can't think of another brand that will sell you a laptop with two screens, one of which is a 120Hz OLED panel, all crammed into a relatively compact 14-inch footprint.

Welcome, then, to Asus's latest masterwork, the Zenbook Pro 14 Duo OLED. And what a machine it is. That OLED panel? It only covers fully 100 percent of the demanding DCI-P3 digital cinema color space. That's better than most pro-grade content creation monitors can muster. Both panels are also stylus and inking compatible, the connectivity is outstanding, there's some proper audio and a half-decent GPU, not to mention one of Intel's finest mobile CPUs. Oh yeah. This thing is loaded.

The main 14.5-inch OLED panel rocks 2,880 by 1,800 pixels in a 16:10 aspect arrangement and cranks out 550 nits of brightness and 0.2ms response to go along with the 120Hz refresh. The secondary screen is IPS rather than OLED and 12.7-inch diagonal, but the same panel width and horizontal resolution of 2,880 pixels. Both screens are compatible with Microsoft Pen Protocol styluses.

Doing the heavy lifting is Intel's mighty Core i9-12900H with six Alder Lake era performance cores and eight efficiency cores, while graphics are via Nvidia's GeForce RTX 3050 Ti. Rounding out the main features are 32GB of DDR5 memory and a 1TB Samsung PCIe Gen 4 SSD. It's really only the latter that seems a little stingy in an otherwise epic list of specs.

Finer details include dual USB-C ports with Thunderbolt 4 support for uber-fast access to external storage, an SD Express 7.0 card reader, a legacy USB-A port in high-speed 3.2 spec, and an HDMI 2.1 port for 4K output at 120Hz. Connectivity is amply covered by WiFi 6E and Bluetooth 5.2. Along with an unexciting 720p webcam, you get a four-array microphone and a speaker system by Harman Kardon. The battery is a 76Wh affair, so pretty beefy for a 14-inch laptop. But then it needs to be with all the display hardware to power.

If that's the specs in full, arguably the really interesting aspect of this laptop involves ergonomics and usability. Do the dual screens actually make sense? The engineering is certainly slick. As you open the lid, the lower screen hinges up to not only provide better viewing but also increased airflow.

On the other hand, the shallowness of the secondary screen could be an issue. The shape means it's not much use for web browsing or even for an email client. You could use it to host collaborative tools such as Slack or maybe a streaming media client like Spotify. For sure, it's a breeze to arrange windows and swap applications between the two screens using Asus's software tools.

But the second screen does by far its best work when you load it up with toolbars, timelines, palettes, and content creation control elements. Then it really starts to make sense. The catch is that the whole design inevitably crushes the keyboard to the bottom of the chassis and pushes the trackpad to the bottom right. It's still a nice keyboard, but the ergonomics are hardly ideal.

Nor, strictly speaking, is the performance. The Intel Core i9-12900H is a beast, no question. But it's also somewhat constrained in this chassis, never mind the supposedly heightened airflow. At default settings, the 12900H drops down to 2.9GHz under sustained loads. Switch to the high-performance mode and that increases to 3.2GHz and is accompanied by some serious fan noise. Either way, we've seen that chip run quite a bit quicker in larger laptops.

The battery life of under seven hours of video playback, even with the secondary screen disabled, is a bit disappointing too. All of which makes the Zenbook Pro 14 Duo OLED a bit niche. It's beautifully built and, if you really make use of those dual screens, it could be killer. But the compromises those two screens impose are also real. **–JEREMY LAIRD**

BENCHMARKS

	Asus Zenbook Pro 14 Duo OLED
3DMark Fire Strike	12,718pts
Cinebench R20 (multi-core)	5,558pts
GeekBench 5 (single-core)	1,713pts
GeekBench 5 (multi-core)	11,930pts
PCMark 10	6,505pts
Battery Life	6hrs 54mins
Crystal Disk Mark Read	6,390MB/s
Crystal Disk Mark Write	5,150MB/s
Total War: Three Kingdoms (1080p, Ultra)	44fps
Metro Exodus (1080p, Ultra)	42fps

VERDICT
7

Asus Zenbook Pro 14 Duo OLED

+ TERRIFIC TWOFER Stellar screen tech; excellent connectivity; fab build quality

− DOUBLE TROUBLE Compromised ergonomics; disappointing battery life.

$2,499 (estimated), www.asus.com

SPECIFICATIONS

CPU	Intel Core i9-12900H (14-core)
Graphics	Intel Iris Xe, Nvidia RTX 3050 Ti 4GB
RAM	32GB DDR5
Screen	14.5-inch 2880 x 1800 120Hz OLED, 12.7-inch 2880 x 864 IPS
Touch input	Capacitive multi-touch with stylus
Storage	1TB NVMe SSD
Ports	2x USB Type-C with Thunderbolt 4, 1 x USB-A 3.2, SD card, HDMI 2.1, 3.5mm audio jack, SD card reader
Connectivity	WiFi 6E, Bluetooth 5.2
Battery	76Wh
Camera	720P webcam
Dimensions	2.74 x 8.85 x 0.77 inches
Weight	3.75lbs

Asus's latest portable packs two screens, one of which is a super-slick 120Hz OLED panel.

ASUS Zenbook Pro OLED
ASUS Zenbook
12:00
31/05/2022

Razer Blade 15 Advanced (2022)

Be careful what you wish for…

A LAPTOP WITH a 4K 144Hz display? That's impressive. But does it actually make sense? Before we get to the answer, let's cover off the new Blade 15's speeds and feeds. The 4K screen is a 15.6 incher, an IPS panel described as the 'Creator' option—you can also opt for 360Hz 1080p and 240Hz 1440p alternatives—and backed up with impressive 100 percent coverage of the demanding DCI-P3 digital cinema color gamut.

To that, you can add the cream of the available crop of performance laptop components. That's Intel's mighty Core i9-12900H CPU with six high-performance cores and eight efficiency cores, plus 32GB of the latest 4,800MHz DDR5 memory. On graphics duty is the finest mobile GPU known to man, the Nvidia GeForce RTX 3080 Ti with 16GB of VRAM. And you get a 1TB PCIe 4.0 SSD, too.

It's all wrapped up in Razer's familiar 15-inch chassis. Available in any color so long as it's black, the main chassis remains one of the better-built all-alloy affairs out there, though there's just a touch of flex in the keyboard bed. The keyboard, incidentally, is per-key RGB backlit and fully programmable with all the usual effects.

With such a minimalist design, it's hard to argue that it's dated. But it certainly has less screen-to-body ratio than something like an edge-to-edge Dell XPS laptop with its near non-existent bezels. As for connectivity, there are three USB 3.2 Gen 2 Type-A ports, two USB-C sockets, one of which has Thunderbolt 4 support, an HDMI port, and an SD card reader.

It's also just 0.67 inches thick, which is slim for this class of laptop, and weighs in at 4.4lbs. That immediately has us wondering about thermal performance, to which Razer retorts with its latest upgraded vapor chamber cooling system, with more fins and a larger fluid capacity than before. We, of course, will make our own judgments.

Set the Blade to full reheat using Razer Synapse app and the Intel Core i9's clock speeds are initially decent under heavy all-core workloads like rendering. You're looking at an initial 3.7GHz to 3.8GHz. However, those speeds fall away pretty quickly, eventually leveling out at 2.9GHz to 3.0GHz after a few minutes.

That's not terrible, but bigger, thicker laptops can produce at least 10 percent more performance using this same chip. As for GPU performance, it's a similar tale. Inevitably, the slim chassis limits clock speeds. Indeed, Nvidia says the 3080 Ti GPU's Boost clock can vary between 1,125MHz and 1,590MHz depending on the thermal properties of a given laptop. The Blade runs at that 1,125MHz minimum.

It still makes for an impressive performance for a portable. And even this low-clocked 3080 Ti will beat a 3070 Ti, say, in a larger notebook with better cooling. But that finally brings us back to our earlier query. Does a 4K panel running at 144Hz on a laptop make sense?

In gaming terms, nope. There's no way even the 3080 Ti is putting out frame rates good enough at 4K to make use of that 144Hz refresh. Playable frame rates? Just about. *Total War: Three Kingdoms* returns an average of 28fps at 4K with ultra settings, by way of example.

On a final note, the 80WHr battery is good for about six hours of video playback, which is OK but won't allow all-day operation away from the mains. All of which makes the latest Razer Blade a pretty similar proposition to previous versions. It's a slick package with a lot of grunt, but there is undeniably a price to be paid, both up front in cash and down the line when it comes to performance and staying power. **–JEREMY LAIRD**

VERDICT
7

Razer Blade 15 Advanced 2022

⊞ **SAMURAI SWORD** Sleek chassis; lovely build quality; uber spec list.

⊟ **RUSTY FLICK KNIFE** Seriously pricey; thermal constraints are fairly apparent.

$3,999, www.razer.com

BENCHMARKS

	Razer Blade 15 Advanced 2022
Cinebench R23	15,746 (Index)
3DMark Firestrike	23,131 (Index)
PCMark 10	7,109pts
Metro Exodus 1080p Ultra	79fps
Metro Exodus 4K Ultra	40fps
Total War: Three Kingdoms 1080p Ultra	91fps
Total War: Three Kingdoms 4K Ultra	28fps
Crystal Disk read	6,670MB/s
Crystal Disk write	4,932MB/s
Crystal Disk 4K read	91MB/s
Crystal Disk 4K write	232MB/s
4K x265 encode	10.6fps
Battery life (1080p video playback)	5h 48m

SPECIFICATIONS

CPU	Intel Core i9-12900H (14-core)
Graphics	Nvidia RTX 3080 Ti 16GB
RAM	32GB DDR5
Screen	15.6-inch 3,840 x 2,160 144Hz IPS
Storage	1TB NVMe SSD
Ports	2x USB Type-C (one with Thunderbolt 40, 3x USB-A 3.2, HDMI 2.1, 3.5mm audio jack, SD card reader
Connectivity	Wi-Fi 6E, Bluetooth 5.2
Battery	80WHr
Camera	1080P webcam

Looks familiar: But Razer's latest Blade 15 Advanced is all-new inside.

The Acer Predator GD711 projector has been designed to look like gaming hardware.

Acer Predator GD711

A solid projection selection

PREDATOR
PREDATOR

GAMING PROJECTORS are a niche market right now, with many projectors focusing on standard media playing rather than games. Some manufacturers have stepped up, such as BenQ with its chunky X1300i gaming projector last year. The latest brand to take a shot at this market is Acer, with the Predator GD711.

If the reflective Acer Predator logo on the top doesn't give it away, the sharp lines and triangular patterning on the sides of the unit make it clear this is a gaming product. But it's unassuming for a piece of gaming kit, free of RGB lighting, and should look at home in any room.

The first thing we noticed upon firing up the GD711 was the lack of a zoom feature, an egregious exclusion in any projector. A rolling wheel on the top of the unit allows you to adjust the focus for an ultra-sharp image, but to adjust the size of the projection you're limited to altering the video output from your device itself or physically moving the projector around.

Once the GD711 is set up, the picture quality is incredible. The sharpness of detail at 4K resolution is amazing, and there's a whole bunch of display presets to choose from, including one specifically for soccer games. The brightness is excellent, making the GD711 usable even without a black-out home cinema setup.

The refresh rate at 4K is limited to 60Hz, but shifting down to 1080p allows up to a speedy 240Hz, ideal for eSports games where framerate is everything. Variable refresh rate technology lets the projector adjust the refresh rate on the fly to reduce tearing and stuttering. We also didn't notice any appreciable amount of input lag while gaming on the GD711.

This projector is no slouch for cinema uses, either. Colors are vibrant and blacks are almost as solid as a similarly priced TV. HDR10 capabilities and a 2,000,000:1 contrast ratio further sweeten the deal. The LED lamp means that the GD711 never gets too warm, and can run for days without overheating. Acer claims a lamp lifespan of 30,000 operating hours, an undeniably impressive figure.

The GD711 runs a simple Android-based operating system that includes Aptoide TV, which theoretically lets you run a limited selection of apps such as Netflix, but we found it to be buggy. Fortunately, it's easy to plug and play with a laptop or desktop PC, via either an HDMI cable or the wireless USB dongle, which slots into the rear of the projector.

Although there's a set of buttons on the top of the projector, it comes with a small infrared remote. Acer says it is coated with a 'silver-ion antimicrobial agent' that keeps germs from building up on the remote. Unfortunately, the remote feels a bit cheap; it's plain matte-black plastic, with rubber buttons that wobble around too much in their housings.

The GD711 comes with a host of features, including the auto-keystone mode that compensates for any amount of distortion caused by the projector's positioning which works well. Other features of note include HDMI Power On, which switches on the projector when it detects an input signal, and support for 3D content via DLP Link 3D.

But where the Predator GD711 falls down is the 10W integrated speaker. The maximum volume is impressive, but the overall audio performance is poor, with little bass and a tiny quality to higher notes. At least this won't be a dealbreaker for most potential buyers, because if you can afford the $1.5k price tag, you probably already have a solid home speaker system. –**CHRISTIAN GUYTON**

VERDICT
7

Acer Predator GD711

+ HOME CINEMA Amazing refresh rate; impressive sharpness at 4K; zero cooling issues.

– HOME INVASION No zoom is a problem; integrated speaker isn't great; remote feels cheap.

$1,499, acer.com

SPECIFICATIONS

Projector type	LED
Native resolution	UHD 3840 x 2160
Refresh rate	240Hz (1080p), 60Hz (4K)
Brightness	4000 lumens
Projection size	Up to 300-inches
Connectivity	Wi-Fi 5, Bluetooth 5.0
Ports	2x HDMI 2.0, USB-A, USB 5V DC Out, 3.5mm audio jack, DC in
Dimensions	12.6 x 9.1 x 4.3 inches
Weight	6.8lbs

Samsung has its eye on Apple
with its new M8 Smart Monitor

Samsung M8 Smart Monitor

Care for some SmartTV and 4K monitor fusion?

© UNSPLASH

A SINGLE DEVICE for all your computing and media consumption needs? That could be the Samsung M8 Smart Monitor. It not only integrates Samsung's full SmartTV platform, it even supports basic web browsing without the need to hook up a PC. More realistically, most users will be plugging a laptop in via the M8's slick, single-cable USB-C interface to get any serious computing done. But the M8's SmartTV functionality and funky design, available in either white or a choice of pink, blue, or green-tinted pastel shades, certainly add a whole new dimension.

Hold that thought while we give the specs a quick scan. This is a 32-inch monitor with a VA rather than an IPS panel. That's not a huge surprise, given VA is Samsung's go-to panel tech. It helps boost static contrast, which is rated at 3,000:1, far better than any IPS monitor. But while basic HDR10 decoding is supported, this isn't a true HDR monitor. There's no local dimming of any kind and the brightness tops out at 400 nits.

That's pretty punchy for an SDR monitor. Just don't confuse it with a miniLED monitor capable of socking it to you with 1,000 nits of brightness. Resolution-wise, we're talking full 4K or 3,840x2,160 pixels running at 60Hz. This is not one of the new breed of high-refresh 4K monitors. Pixel response is rated at an adequate but not outstanding 4ms and Samsung doesn't make any exotic claims when it comes to color coverage.

In other words, this monitor isn't aimed at content creation pros or hardcore gamers. It's more of an all-round computing and media consumption device. This brings us to the M8's stand-out feature, the SmartTV integration. It comes with an IR remote control and the usual shortcut buttons to the most popular streaming apps, including Amazon Prime, Netflix, and Disney+.

There's also the web browser plus wireless connectivity with screen mirroring. It even has productivity apps like Microsoft 365 installed and supports a keyboard and mouse. At a stretch, you could get quite a bit of computing done on the M8 without actually plugging in a computer. Question is, would you want to?

We'd say no, primarily because the SmartTV interface doesn't run at the screen's native 4K. Likely it runs at 1080p, but whatever the resolution the image quality is quite soft and the desktop screen space is relatively cramped given the 32-inch panel size. The M8 streams media at the full 4K, it's just the interface and apps that aren't rendered at 4K. It's also worth noting that the built-in speakers are pretty pathetic. So if you're serious about watching TV and movies, you'll want a separate set of speakers.

What you won't need is a webcam. Samsung bundles one of those and it clips cleverly onto the top of the screen via a magnetic connector that also provides power and data. The camera adjusts for tilt, but only upwards, which isn't much use. It supports digital face-tracking but for now that only works with Google's Duo video calling app.

If you're wondering about image quality, the usual 4K upsides including crisp fonts and lots of desktop real estate are present. But the viewing angles aren't great and neither is the backlighting. It's an OK 4K VA panel, but certainly nothing special. The same goes for the build quality. The slim bezels and herringbone-style texture on the rear we like. But the flimsy plastics and the way the whole thing wobbles when you jab it lightly isn't going to have the likes of Apple rushing out to re-engineer its latest Studio Display, that's for sure. **–JEREMY LAIRD**

VERDICT

7

Samsung M8 Smart Monitor

+ HOORAY FOR 4K Funky styling; huge feature set includes SmartTV.

− SUCKS TO BE SAMSUNG Merely OK image quality; feels a bit flimsy.

$699, www.samsung.com

SPECIFICATIONS

Screen size	32-inch
Panel type	VA
Resolution	3,840 x 2,160
Brightness	400 nits
Contrast	3,000:1
Response time	4ms
Refresh rate	60Hz
Colour coverage	99% sRGB
HDR support	HDR10
Connectivity	USB-C x2, MicroHDMI

PowerColor RX 6650 XT Hellhound

A case of style over substance?

THERE'S A LOT to be said for an attractive-looking graphics card, something that breaks away from the usual trends. PowerColor's Hellhound Spectral White is hardly the first white graphics card to hit the market, but after a decade or more of variations on gray and black cards, it's nice to have the option of something different. Unfortunately, PowerColor then skimps on the lighting, providing only white LEDs on the fans—it still looks cool, but unlike darker cards, the white shroud could have reflected the colors.

Besides the aesthetic considerations, there's not much to differentiate this RX 6650 XT card from others with the same GPU. It has a minor factory overclock, from the reference 2635MHz to a 'blistering' 2689MHz. That's only a two percent increase, close to the margin of error for benchmarks, never mind being able to tell the difference while gaming. PowerColor has also stuck with the reference 180W TBP (Typical Board Power), which also may limit any gains from the overclock.

Case in point: Despite the 12.5 percent increase in memory bandwidth over the RX 6600 XT, the RX 6650 XT was only two percent faster across our test suite. There were a few cases where it was five to six percent faster, but also games where it was tied in performance. As far as we can tell, the higher clocked GDDR6 memory doesn't help performance much, potentially due to higher timings—even 1440p didn't show much of a difference. Whatever the cause, the performance difference between the old and new Navi 23 cards hardly warrants discussion.

Unlike the RX 6950 XT and RX 6750 XT, AMD plans to discontinue the RX 6600 XT and replace it with the slightly faster and more expensive RX 6650 XT. That feels like a mistake, as the increased MSRP potentially puts it into direct contention with Nvidia's RTX 3060 Ti, which also sells for a theoretical $400. Street pricing on the Nvidia GPU hasn't quite reached MSRP, with the cheapest model still going for $480, but we wouldn't be surprised to see prices drop another 10–20 percent by the time you read this.

Considering the RTX 3060 Ti ended up being 30 percent faster on average, and up to twice as fast in ray-tracing games such as *Cyberpunk 2077* and *Minecraft*, spending a bit more on Team Green feels like the way to go. Alternatively, the RTX 3060 offers comparable performance—slower in some games, faster in others—with a theoretical starting point of $330. Right now, both the RX 6650 XT and RTX 3060 are available for $400, and you get 50 percent more memory with the 3060. Nvidia also gives you DLSS support, and while FSR 2.0 might be close in quality and effectively works on all modern GPUs (at least of those that we've tested), there are far more games with DLSS support than FSR 2.0 support at present.

The RX 6650 XT feels very much like an excuse to raise GPU prices. Maybe that would have worked last year but we now appear to be entering a period of oversupply. TSMC's 7nm N7 process now reached full maturity, so prices for chips made using the technology shouldn't be too bad. This is the same N7 as was used for the Radeon 5000-series launch back in 2019. We're unlikely to see a 5nm RDNA 3 replacement for Navi 23 until sometime next year, but the GPU feels a lot more like a part that should cater to the midrange $250–$350 graphics card market rather than a $400 card.

As is generally the case, few graphics cards are truly bad; it's more a question of pricing and value. We feel there are better options in this price bracket right now, but if PowerColor or other graphics card makers can cut the price, the RX 6650 XT could end up as a viable option. Keep your eyes out for any deals, as we expect prices to fall over the coming months. **–JARRED WALTON**

VERDICT
6

PowerColor RX 6650 XT Hellhound

+ **CHILL** Attractive design; good for 1080p; cool and quiet.

− **FRIGID** Puny speed bump; questionable pricing; struggles against the competition.

$399, www.powercolor.com

BENCHMARKS

	RX 6650 XT	RX 6600 XT	RTX 3060 Ti	RTX 3060
10 Game Average	122 / 72	121 / 70	**136 / 86**	108 / 66
Borderlands 3	**204 / 103**	**204 / 103**	199 / 99	154 / 73
Control (DXR)	59 / 37	57 / 37	**101 / 63**	75 / 46
Cyberpunk 2077 (DXR)	23 / 18	22 / 17	**46 / 40**	35 / 30
Far Cry 6	**163** / 119	162 / 115	160 / **123**	130 / 97
Flight Simulator	112 / 67	112 / 66	**154 / 87**	118 / 69
Forza Horizon 5	**179** / 88	175 / 86	155 / **94**	122 / 72
Horizon Zero Dawn	161 / 115	158 / 113	**165 / 126**	143 / 100
Minecraft (DXR)	31 / 26	30 / 25	**66 / 57**	50 / 44
Red Dead Redemption 2	154 / 72	153 / 71	**169 / 89**	136 / 69
Watch Dogs Legion	137 / 74	135 / 72	**150 / 87**	119 / 64

Best scores are in bold. All testing conducted with a Core i9-12900K, MSI Pro Z690-A WiFi DDR4, 2x16GB DDR4-3600 CL16, 2TB Crucial P5 Plus M.2 SSD, Cooler Master MWE 1250 Gold V2. Scores are average framerates at 1920x1080 medium/ultra, with ray tracing enabled in Control, Cyberpunk, and Minecraft.

SPECIFICATIONS

Architecture	Navi 23
Lithography	TSMC N7
Boost clock	2689MHz
GPU cores	2048
Memory	8GB GDDR6
TFLOPS FP32	11.0
Bandwidth	280GBps
TDP	180W
Connectors	HDMI 2.1, 3x DisplayPort 1.4

The 6650 XT comes in stylish 'Spectral White' or the more traditional dark gray, with the same specs and performance.

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computer-1

And Now For Something Completely Different

WE ALL LOVE IKEA, RIGHT? Flat-packed furniture with diagrammatic instructions, plush toys, unpronounceable Scandinavian names, and excellent meatballs, of course. The Swedish chain is a potentially invaluable source of kit for your perfect home PC setup, even partnering with Asus for a line of Republic of Gamers-themed products.

It's surprising that Ikea hasn't attempted to breach the world of PC-building proper, but have no fear; Teenage Engineering, a consumer electronics manufacturer also hailing from Sweden, has an answer to that age-old question: what would a computer case from Ikea look like? That answer is the computer-1 (yes, the lower-case 'C' is intentional).

Although Teenage Engineering made its name in audio hardware, starting with the hugely successful OP-1 synthesizer, it quickly branched out into other areas. Its equipment has been used by successful musicians, from Depeche Mode to Thom Yorke. The company collaborated with Panic to design the retro-styled Playdate handheld games console and has now taken that retro aesthetic to the design of its first PC case.

TEENAGE KITS

The computer-1 is striking, a boxy ITX case with a metal carry handle on top and a vibrant orange paint job that immediately evokes the classic 1980s style Teenage Engineering is keen to emulate. The story behind the design is amusing; when the company first started out, it couldn't find a suitable PC case, so built its own using a laser cutter and high-density board. The original prototype was held together with wooden pegs and unfortunately fell victim to what the manufacturer's website refers to as a 'literal computer crash'.

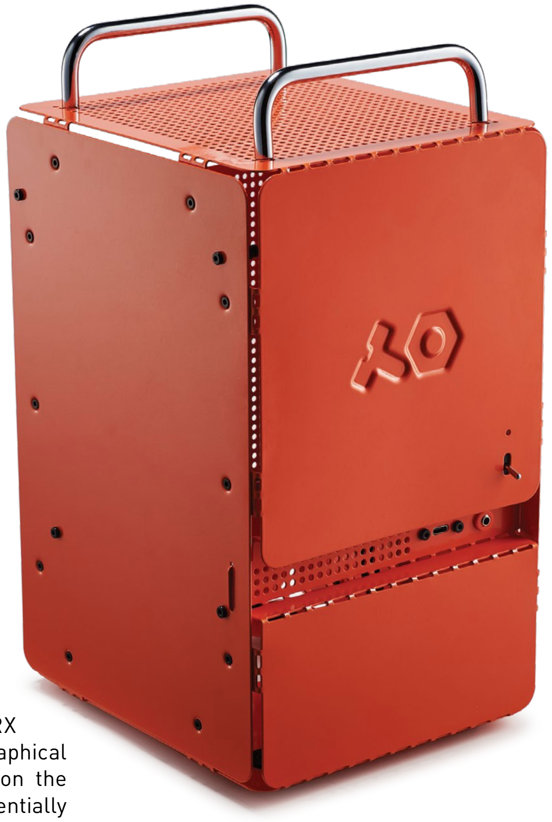
But a few iterations later, we have a finished product. In true Ikea fashion, the computer-1 comes flat-packed in a box less than an inch thick, the different parts neatly packaged in their own slim containers. Although it can be assembled on its own, it has been designed to be put together during a complete PC build, with detailed step-by-step imagery demonstrating when to add each component.

Actually, building this case demands some real attention, as you'll have to carefully bend the aluminum panels and wire the I/O ports yourself. It comes with a specialized tool for assembly and is much harder to take apart than put together, which is a possible stumbling block for users who like to upgrade regularly.

The computer-1 takes an SFX power supply and requires a relatively low-profile CPU cooler (the stock AMD Wraith Stealth fits just fine). There's room in the roof of the case for a compact single-fan GPU, so you could potentially fit an RTX 3060 or RX 6500 XT here if you want more graphical oomph. There are screw holes on the rear panel that allow you to potentially install two 2.5-inch SATA drives, though Teenage Engineering doesn't list this in the product specs for some reason.

As a fully-assembled system, the computer-1 looks incredible. The gaps between the metal panels hint at its DIY nature without exposing too much of what holds this case together, and the top and rear panels are perforated to ensure good airflow. The base and side panel have a round, laser-cut hole for the PSU fan and a single, optional 80mm case fan. Thermal performance is brilliant, though we'd watch out for dust buildup with those exposed fans. The carry handles and lightweight aluminum design make the computer-1 easy to move around, potentially ideal for creatives who need to take their system on the go with them. The front I/O is basic, offering just a USB-C port and a 3.5mm audio jack, but there's hardly room for anything else.

At $195, the computer-1 is pricey for an ITX case, especially one you have to build yourself. But this isn't a generic consumer product, it's a love letter to the creativity of system-building; a delightful piece of precision Swedish engineering that provides more than just a case, but a mechanical building experience too. What seals the deal is the power switch, a tiny spring-loaded lever at the front of the case, which is so much fun to twiddle that it makes us want to crash our PC over and over again. **–CHRISTIAN GUYTON**



VERDICT 8

Computer-1

+ TEEN SPIRIT Fantastic retro aesthetic; very portable; surprisingly sturdy once assembled; power switch is awesome.

– TEENAGE DIRTBAG Tricky to assemble; not designed to be taken apart; undeniably expensive.

$195, teenage.engineering

SPECIFICATIONS

Form	Mini Tower
Motherboard support	ITX
Colors available	Pure Orange
Window available	No
3.5-inch support	N/A
2.5-inch support	x2
Radiator support	N/A
Fan support	80mm (side)
CPU tower clearance	4.7 inches
Graphics card clearance	7.1 inches
Dimensions	6.7 x 7.5 x 12.7 inches
Weight	1.84lbs

Corsair K70 RGB Pro

Premium price tag for a premium keyboard?

CORSAIR ISN'T EXACTLY unfamiliar with keyboards. The company has an impressive arsenal and a presence in most types of keyboard markets. The K70 RGB Pro follows on from the K70 RGB MK.2 with a refreshed sleek design and some performance upgrades. At just under $160 with Cherry MX Brown switches, it's pricey, but is it worth splashing out to add this to your desk?

First of all, the K70 RGB Pro feels solid to the touch. Made of an aluminum frame with a durable plastic housing and weighing around 2.5lbs, this keyboard feels premium for the most part, but that impression is let down by a few sharp edges. The full-sized model on review here looks more professional and sleeker than before. The minimalistic design is a step in the right direction.

The media controls have been shifted to the edges—on the right-hand side, you'll find the media playback controls and above the number pad, you have stop, previous, play/pause, and next keys. Unusually, these feel like membrane switches and don't follow the design and key switches of either the rest of the keyboard or the rest of the media switches. Though they feel high-quality, it seems like an odd choice.

Above this is the mute button next to a nicely textured scroll wheel. It's easy to use and has a premium dialed weight to it. The mute button is a light and clicky switch, like a mouse button, but doesn't feel cheap. There are more of these switches to the far left of the keyboard, where there is also a profile button, brightness, and lock button functionality.

Underneath the board are four rubberized feet that do a good job of keeping the keyboard in place even when using both of the two height options of the stands. There is also a star-like channel system underneath for the USB-C cable to follow, which is handy for cable management geeks, including us. Thankfully, the cable is detachable in case of any future problems although it is braided. This connection is recessed into the board though, so it won't be compatible with most custom right-angle cables.

Next to the cable is a feature that's almost hidden away, the tournament switch. This locks macros and lighting for when you're in a competitive game and prevents any accidental button presses from happening. One more point of note is the wrist rest that comes with the board, though our sample didn't quite sit flush and had a slight bend towards the middle. For the price tag, it'd be nice to have a memory foam rest, but it's still more comfortable than not having one.

So, what about its performance and how the keys feel? Fortunately, the keys are the more expensive PBT variety, although you might expect that at this price point. They are double-shot keycaps and feel durable, but have an almost cheap-feeling texture to them. This material offers more grip over ABS but we'd like a more premium feel at this price point. As for the switches, it's a thumbs up from us. With Cherry MX mechanical switches, the K70 RGB Pro doesn't suffer in this area. Specifically, we have the RGB Brown variant, which offers tactile feedback halfway through the keypress. They aren't too loud, so using this both as a gaming keyboard and for work shouldn't be a problem.

The RGB per-key lighting is what you'd expect from Corsair. The light is emitted and dispersed evenly with five levels of brightness from default and further controlled through Corsair's iCUE software. This board also features impressive performance to pair with the switches, as it uses AXON, Corsair's hyper-processing technology. In short, it has a polling rate of up to 8,000Hz, whereas the previous model had 1,000Hz, reducing input delay for competitive gameplay.

This K70 RGB Pro is great for gaming with a responsive input and is generally comfortable to use during long sessions. Although it has a nice weight to it, feels sturdy, and is mostly considered a premium board, it does have a few sharp edges and the keycaps feel slightly cheap. The K70 RGB does however have a premium design and the performance is what you would expect at this price point. It's just a shame that as a full package, there are better alternatives in this price bracket. **–SAM LEWIS**

VERDICT 7

Corsair K70 RGB PRO Mechanical Gaming Keyboard

+ **PRO** Crisp Cherry MX switches; fast polling rate; removable cable; strong build quality.

− **SEMI-PRO** Poor wrist rest; no USB pass-through; quite pricey; a few cheap feeling areas.

$160, www.corsair.com

SPECIFICATIONS

Switches	Cherry MX Brown
Switch durability	100 million+ presses
Design style	Full size
Connection	Wired USB 3.0 or 3.1 Type-A
Wrist rest	Magnetic detachable, soft touch
Weight	2.54lbs

Logitech Lift Vertical Ergonomic Mouse

Vertical wireless mouse with compact size and price

WE'RE SURE many of you are old enough to remember 1994, when Microsoft released its first ergonomic keyboard, named the Natural Keyboard. It was split down the middle and angled to fit the natural angle at which your hands rest when you place them on a desk. Anyone who used it would undoubtedly have had a strange learning curve, like moving from a bicycle to a unicycle—kind of the same but also completely different.

It's a similar feeling with the Logitech Lift Ergonomic Mouse. As Logitech describes it, you grasp the mouse in a "natural handshake position" which puts less stress on the forearm and wrist than a traditional mouse. From the moment you first touch the Lift, it's apparent how much better this design is for your arm than a traditional mouse—it feels like the right way to be holding a mouse.

Clearly, ergonomics is the big selling point here, and those looking for customization or advanced features should look elsewhere. There's a lot you can do in Logitech's Logi Options+ app, including controlling the sensitivity and customizing buttons, but you can't change the scroll wheel from smooth to clicky nor can you add weights for personal taste. We also wouldn't recommend this mouse for gaming, as it doesn't feel as accurate or as fast as a gaming mouse.

So with ergonomics in mind, it's great to see Logitech do both left- and right-handed versions of this mouse to serve the often-neglected lefty market. They also specifically designate this mouse for those with small to medium hand sizes. Though I personally fall within this category, those with larger hands may want to try before they buy, because their fingertips may reach just over the mouse buttons. The existing MX Vertical mouse is bigger for people with larger hands.

So what do you get with the Lift Vertical? Well, as a wireless mouse, it comes with Logitech's Logi Bolt USB Receiver, a tiny dongle that can be stored in the base of the mouse and which offers a secure, uninterrupted, and lag-free experience. If you're in the Logitech ecosystem with one of its recent keyboards, then one dongle can support up to six devices, which is neat. If you prefer, you can also use Bluetooth, which worked fine for us but may be less dependable if you're in a busy office.

There are also some pretty nifty features on the Lift. You can pair with up to three devices across the dongle or Bluetooth, so if you use multiple machines you can swap between them quickly. Logitech also has a feature called Flow, which means that if you have a desktop and a laptop next to each other, you can scroll across from one to another, and even copy and paste text and files between them. It's a niche feature, but those who use it will no doubt fall in love with it. It's slightly annoying that you can't charge the mouse over USB, but its single AA battery lasts for up to two years, so it's not a major issue.

The mouse itself is slightly heavier than a traditional mouse at 125g (my daily driver is the Logitech G903 Lightspeed Wireless, at 110g). The design means you won't be able to pick it up like you can other mice—it's difficult to lift given the grip style. The face of the mouse features a left and right button like on every other mouse, a scroll wheel, and a button to quickly switch between fast and slow cursor speeds. The other side where your thumb sits has two more buttons, which can be customized in Logitech's software to do things like go forward and back, or copy and paste. Even better, the software allows you to change these actions in different applications, so they can do one thing in Google Chrome and another in Microsoft Word, for example. We found the biggest annoyance of the mouse was the scroll wheel—your middle finger rests naturally on the wheel on a traditional mouse, but it feels slightly more awkward on the Lift. We ended up dragging our finger upward on the wheel as a result, which made a slightly annoying sound as we did so.

Once you get used to a different style of mouse, there's a lot to like about the Logitech Lift. It feels as though it reduced the strain on our arm, it's got some great features, and is reasonably priced. It's a neat little package. **–GUY COCKER**

VERDICT 7

Logitech Lift Vertical Ergonomic Mouse

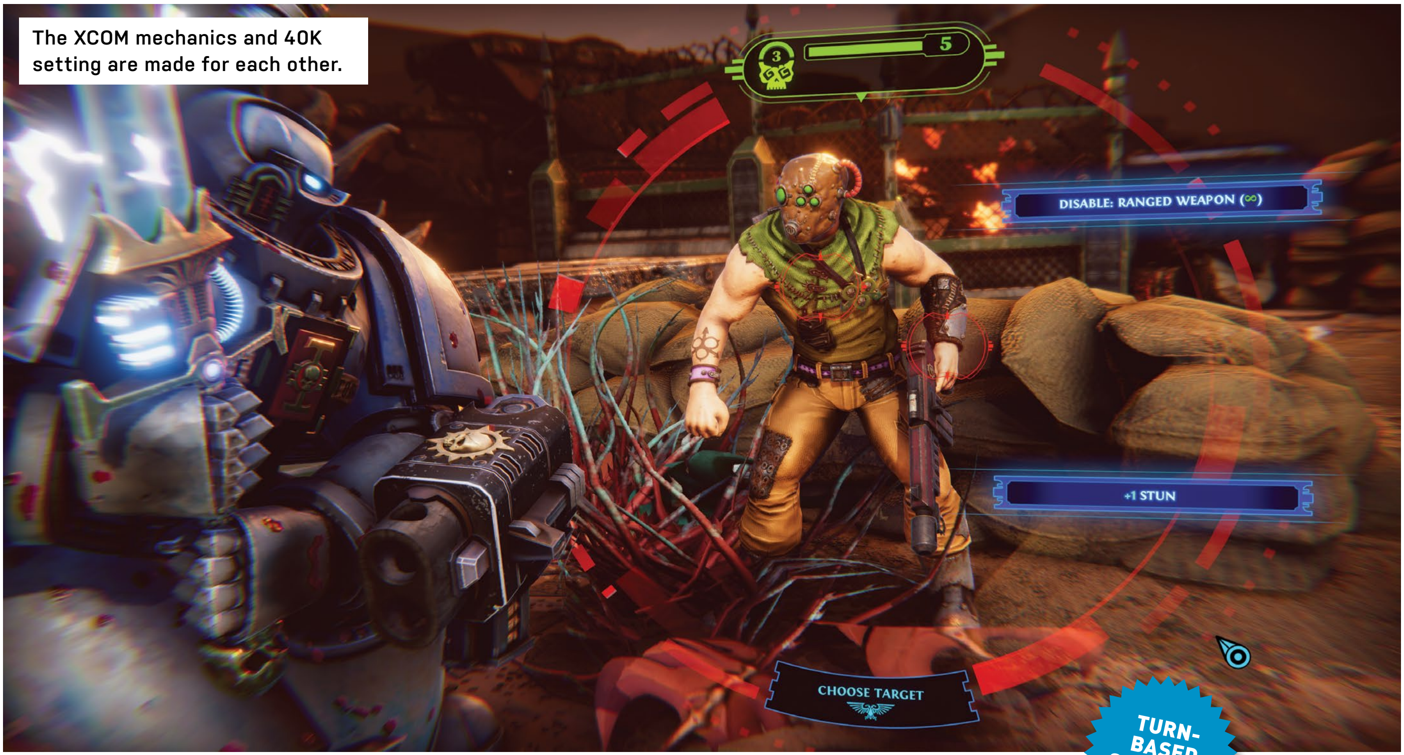
+ LIFTED Long battery life; customizable buttons; comfortable to use.

− SUBDUED Scroll wheel feels awkward; no USB charging; takes some getting used to.

$70, www.logitech.com

SPECIFICATIONS

DPI range	400-4000dpi
Buttons	6 (left/right-click, back/ forward, middle button, scroll-wheel with middle click)
Battery Life	2 years
Connection type	Logi Bolt USB receiver, Bluetooth Low Energy
Wireless range	10m
Operating Systems	macOS 10.15 or later, Windows 10, 11 or later
Dimensions	71 x 70 x 108mm
Weight	125g



The XCOM mechanics and 40K setting are made for each other.

TURN-BASED STRATEGY

Warhammer 40,000: Chaos Gate – Daemonhunters

Grey Knights vs. the forces of Chaos in XCOM-alike

THOUGH TECHNICALLY A SEQUEL to *Chaos Gate* from 1998, *Daemonhunters* has little to do with the older title, apart from being a turn-based strategy, its *Warhammer 40,000* setting, and the choice of the hordes of Chaos as the enemy. While the earlier game used the *Soldiers at War* engine to power its grimdark mass murder, *Daemonhunters* is in thrall to a completely different title: *XCOM*.

And this is a good thing. *XCOM 2* is one of the few games from the past five years to get the coveted *Maximum PC* 'Kick-Ass!' award. There are far worse things to be inspired by. And by dressing up *XCOM*'s turn-based tactics in mutated green Nurgle pants and Terminator armor, you're basically guaranteed a good time.

Daemonhunters swaps *Chaos Gate*'s Ultramarines, the by-the-book Space Marines who are as close to 'good guys' as the 40K universe will allow, for the Grey Knights, a group of anti-demon troops kitted out with specialist weapons and psychic powers. They also come with some of the best bits of *XCOM*, including overwatch and reaction shots, plus enough armor to stand in the open for a bit and not worry too much about anything less than a direct hit from explosives. *XCOM*'s most annoying trait, the to-hit percentage that saw even trained snipers fluff a 90-plus percentage shot occasionally, has gone: if you can see the enemy, and it's in range, you can hit it with only the damage you do varying, as befits genetically engineered seven-foot supermen in one-ton steel boots.

And while the Grey Knights are happy to stand off and pummel the enemy with heavy fire from afar, each member of your squad is also armed with a fearsome melee weapon they're itching to leap into close combat with. Far from being the boy band they appear in pre-battle cinematics, your Grey Knights squad is absolutely lethal from the moment they touch down, combat experience only making them more dangerous and better-equipped. When even your grenades have 'wrath' emblazoned on them, you know you're a force to be reckoned with.

The lack of a stage where your troops are puny recruits armed with rusty weapons means the enemies can go hard right from the start too. While roaming the galaxy in your flying cathedral of a spaceship, you run into an Inquisitor, a polite young lady with a penchant for embossing the letter I into her armor and with the power to requisition your ship and all on it (including a remarkable tech priest, who is more machine than human) to serve her needs.

She drags you into a mystery concerning The Bloom, an innocuous-sounding virus spreading on nearby planets. Not much investigating later, you realize you're fighting a disease released by the forces of Nurgle, one of the 40K setting's four

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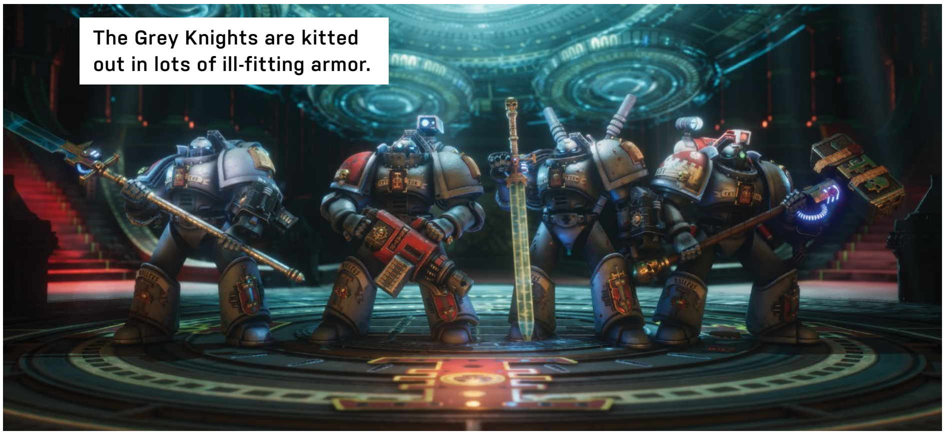
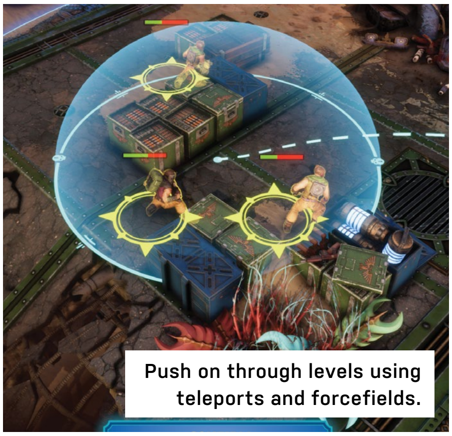
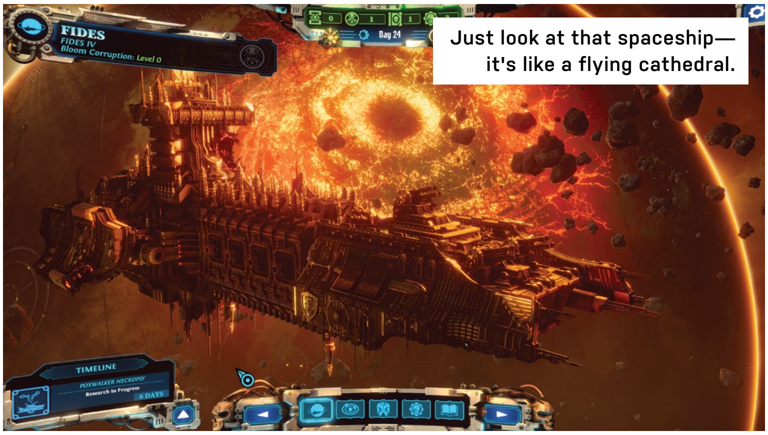
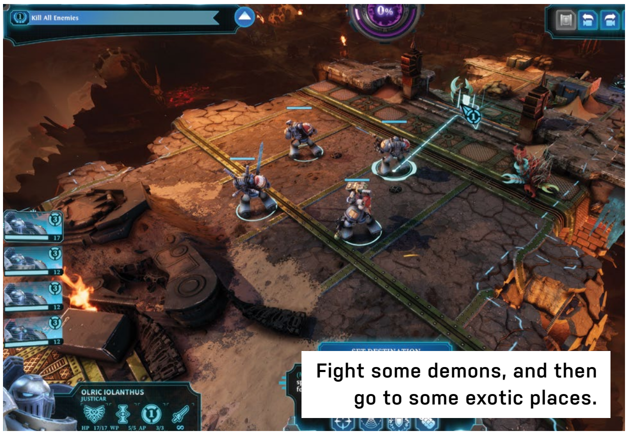

The Grey Knights are kitted out in lots of ill-fitting armor.


Push on through levels using teleports and forcefields.


Just look at that spaceship—it's like a flying cathedral.


Fight some demons, and then go to some exotic places.

chaos gods and the jolly grandfather of everything rotten, pestilent, and diseased. While this means the cultists you face are just as likely to explode in a shower of their own pus as they are to fire back accurately, it also puts tough Chaos Space Marines and psychics (who might as well be wizards) on the enemy roster.

BLOOMING ENEMIES

As The Bloom spreads, you're given multiple targets on the strategic map and a number of days to reach one. In transit, your troops heal and you fix up your ship, which has taken damage in a previous campaign against a greater demon that took out your commander and thrust you into the big chair. You quickly realize there's no way to get to all the missions before the timer runs out and The Bloom intensifies, making them harder.

The Bloom is always notching up its local presence, and when the meter is full the bad guys may get a fun mutation, or something nasty added to the forces against you, thanks to a Warp Surge. It's all geared to push you through the level, using teleports, forcefields, and high ground to your advantage instead of lingering in cover taking pot-shots at 60 percent accuracy.

Moves are strung together using the familiar action point system that sees you attempt to extend your turn for as long as possible by exploiting moves that return AP to your characters. Happily, for at least one class of Grey Knight, this means killing. A tightly grouped band of enemies can be carved through with a sword or halberd while your troopers set overwatch and attempt to annihilate the rest on their own turn. Running into position while using all your AP is a valid tactic in the beginning phase of a fight, though slower-moving heavy-weapons troopers can feel under-used, their ability to set everything on fire often taking second place to a character with a glowing sword bouncing about and teleporting away while another uses his psychic powers to make enemies cower in fear.

Character animation is wonderful, with a sense of heft to the heavily armored Knights that means it's lovely to see them scramble up to rooftop height as if all that clanking metal meant nothing. Video communication between your ship and Grey Knight HQ reveals that they wear their armor all the time, not even slipping into something more comfortable when kicking around at home on Titan, so we guess they've gotten pretty used to it.

The whole game is steeped in the lore and look of *Warhammer 40,000*, and if that's not your thing then you're going to have a serious problem with this game. Happily, Nurgle is a great choice of faction to pit the Knights against, as it's just as happy 'upgrading' its followers with tentacles as it is teleporting demons to the battlefield. You never quite know what's coming next, especially once the action turns from planet-hopping industrial areas to the realm of chaos itself.

The 40K setting and *XCOM* mechanics are made for each other, but at least at the beginning, it can feel a little samey. Your spaceship is a thing of beauty and your troops look amazing, but when you teleport down to yet another train yard to fight the guys out of *Borderlands* once again, you start to wonder where this is all going. Thankfully, it goes to some wonderful places, and with solid tactical combat behind it, isn't afraid to let rip with the weirdness. **–IAN EVENDEN**

VERDICT
9

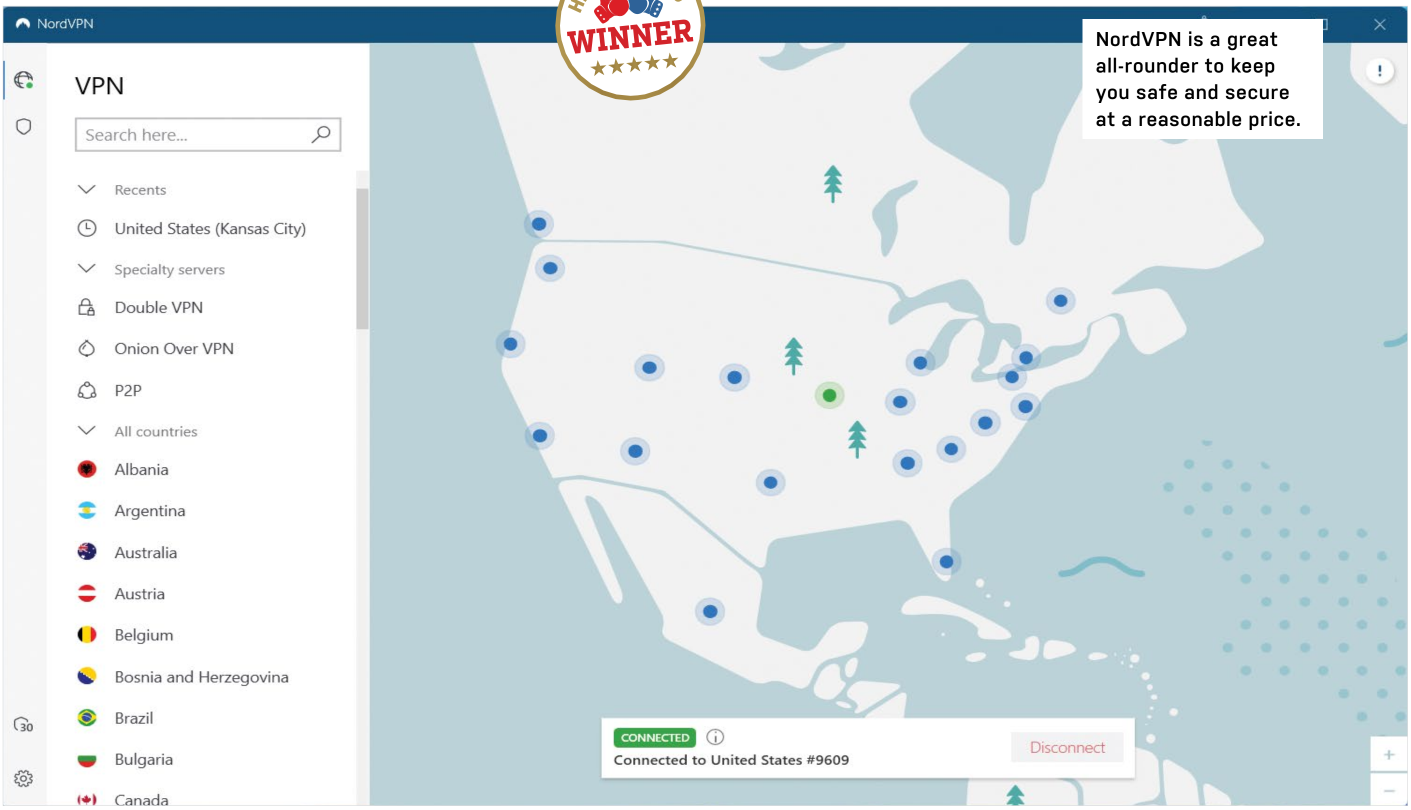
Warhammer 40,000: Chaos Gate-Daemonhunters

NURGLE Excellent world-building; great combat; superb graphics.

GURGLE Occasionally wonky AI; some samey levels.

RECOMMENDED SPECS CPU, i7-7700/ Ryzen 7 2700. RAM, 16GB. GPU, GTX 1060/ Radeon RX 580.

$45, www.chaosgate.com, M-rated



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HEAD TO HEAD WINNER

NordVPN is a great all-rounder to keep you safe and secure at a reasonable price.

NordVPN vs. ExpressVPN

The battle to protect internet security and privacy

AS YOU MAY ALREADY know, a virtual private network (VPN) is a service that hides your IP address and virtual location whilst encrypting your internet traffic. This vastly improves your online security and privacy, which is something we should all be keeping tabs on these days.

Although the old adage about "nothing to hide, nothing to fear" often comes up in discussions about internet privacy, a VPN does more than simply hide your internet browsing history. In an era when almost our whole lives are spent on the internet, it goes without saying that you don't want prying eyes stealing your data or getting up to no good with your valuable information, whether that's your financial details, personal information, photographs, or employment history.

If you're opting to go down the VPN route, it's important to choose one that you're happy with and feel secure using. Thankfully, there are plenty of VPN services around but two of the most popular choices are ExpressVPN and NordVPN. The two offer similar packages that strongly rival each other and while they aren't new, they do offer most of the features that VPN users will be after.

VPNs can be traced back to the mid-1990s when Microsoft employees created PPTPs (point-to-point tunneling protocols) to form a secure tunnel between LAN or WAN connections by encrypting data between users. VPNs have come a long way since then, but their uses remain similar to this day.

There are many reasons why you may want to use a VPN tool, whether it's to access a website that is geo-blocked in your home country for gaming, or if you're connected to an unsecured public network. Even something as simple as having the ability to access a different Netflix library from another country may be enough to justify investing in a VPN, but whatever your need, we will outline the key reasons why you may want to choose one of these two popular VPN services.

First and foremost, security is one of the most prominent factors of a VPN. Thankfully, if you choose either NordVPN or ExpressVPN, both have solid security. The two applications have kill switches that prevent potential leaks when a stability issue arises with your internet connection. This essentially stops all internet traffic if the VPN is disconnected. Another key security feature of both applications is ChaCha20 encryption, which is available through both of the service's protocols.

The two also use RAM-only servers, which are a must-have feature as this eliminates the retention of your data. But although it appears to be neck-and-neck for these two VPNs at this stage, NordVPN is a few steps ahead of ExpressVPN with a few extra features, such as Double-VPN servers, CyberSec, and Tor-over-VPN servers, for example. But while these are certainly handy to have, they may not be essential for all users.

We found that when applying security features, it was marginally quicker and easier to navigate on ExpressVPN as the desktop application is slightly smaller to navigate. After all, both are highly secure with certification from ioXt and have been independently audited. In short, both these VPN services get the thumbs up when it comes to security, with NordVPN just edging ahead in this category.

As for navigating around the application, ExpressVPN was easier, but not necessarily for the best reason. NordVPN's desktop app had more

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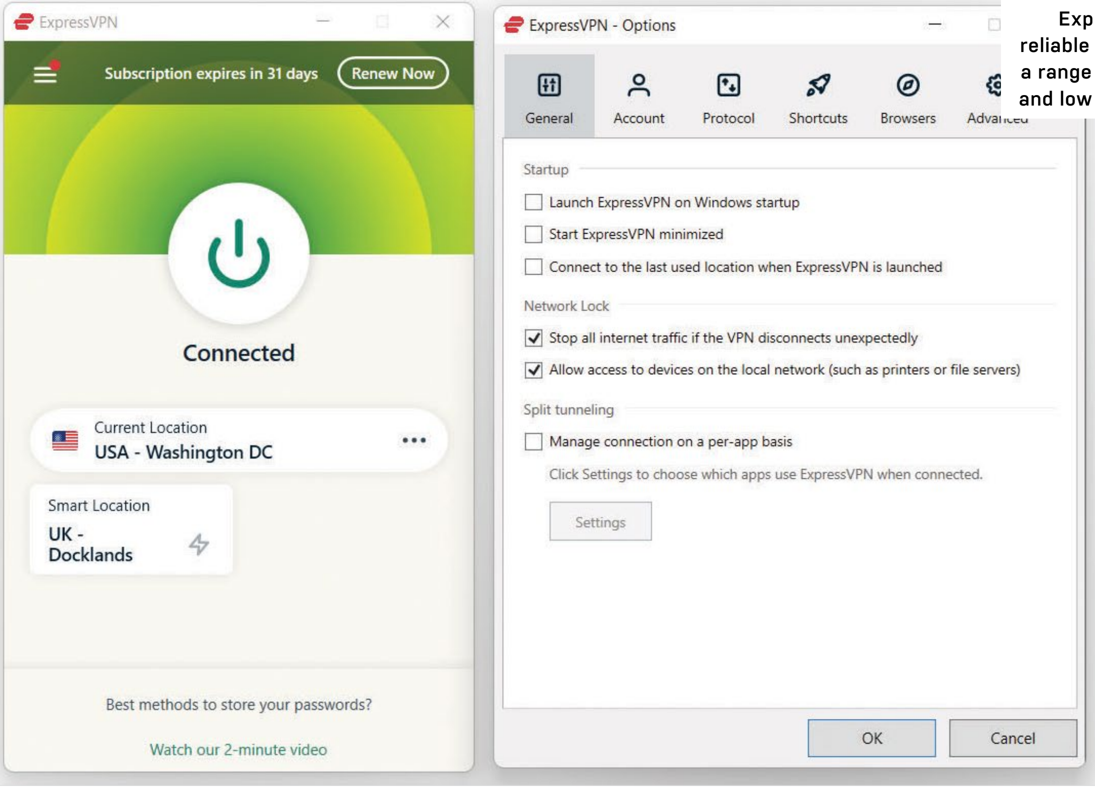

Startup
☐ Launch ExpressVPN on Windows startup
☐ Start ExpressVPN minimized
☐ Connect to the last used location when ExpressVPN is launched

Network Lock
☑ Stop all internet traffic if the VPN disconnects unexpectedly
☑ Allow access to devices on the local network (such as printers or file servers)

Split tunneling
☐ Manage connection on a per-app basis
Click Settings to choose which apps use ExpressVPN when connected.

ExpressVPN is a reliable service with a range of countries and low ping scores.

settings and features to play with, which makes ExpressVPN easier to navigate. The less-is-more approach works here for efficiency but we prefer what NordVPN has to offer and the overall aesthetic of its software. That's not to say that ExpressVPN's design is complicated, as they both have a clean design language. NordVPN is less cluttered and features light colors that are easy on the eye.

On NordVPN's landing page, you're greeted with a world map in which you can pick and choose where you want your IP to appear virtually. There's also a list available down the left side if you want to search or scroll there. ExpressVPN offers a list of countries, but its app opens multiple pop-up windows rather than everything sitting in one window. It's a small issue but NordVPN's application works better with everything in one place. The only benefit to ExpressVPN's design is that if you open it quickly, it doesn't take up much real estate on your screen as you can't expand or open it full-screen.

So another marginal victory for Nord, but how do these VPNs fare when it comes to performance? When running internet speed tests through Ookla with no active VPNs, we received a whopping average download speed of 35Mbps and an upload of 12Mbps—and our Ping was running at 7ms, which wasn't exactly brilliant. When testing both NordVPN and ExpressVPN, we were pleasantly surprised that the internet speed test stayed at a similar level to the bench test. In fact, with ExpressVPN we got lower ping and slightly faster download/upload speeds. Though internet performance doesn't sit at a constant speed and fluctuates all the time, it's good to see that neither service negatively impacts your speed while you're using them.

When streaming across geo-blocked websites, both ran smoothly with no apparent issues. We tested services such as Netflix, YouTube, Spotify, and Tidal and both VPNs gave us access to content that would have otherwise been blocked in our location. Both have a handy smart DNS feature which is great for Smart TVs that don't have a VPN application installed natively. It allows you to gain access to geo-blocked content easily on your TV and when testing, both worked as they should.

As well as streaming services, we tested *Call of Duty: Warzone* with no noticeable performance issues. Using a VPN when gaming can help you to play with different lobbies globally. Yes, this could be seen as a cheeky workaround to play against other players around the world if the ones in your location are too tough to play against, but it works.

So far, it's been difficult to separate these two VPNs with both putting up a good fight. Yet when it comes to pricing, NordVPN leaps ahead of ExpressVPN. Although ExpressVPN offers a similar experience, it is more expensive than its competitor and doesn't deliver all the same features. With a cleaner design and layout, more availability, and cheaper prices, NordVPN takes the victory here. Yet, if you opt for ExpressVPN, you won't be disappointed. It provides reliable performance with great security and a decent desktop design. It's just a shame about the pop-up windows. **–SAM LEWIS**

VERDICT
9
NordVPN

STRONG ARMOUR Great application design; solid speeds; superb security; double VPN availability.

CRACKS IN THE SHIELD Fewer territories available than ExpressVPN.

NordVPN 2-Year Plan $3.99/month
NordVPN 1-Year Plan $4.99/month
NordVPN 1-Month Plan $11.99/month
www.nordvpn.com

VERDICT
8
ExpressVPN

EXPR-YES-VPN Excellent security features; more territories than NordVPN; easy-to-use app.

EXPR-NO-VPN Lacks several key features compared to Nord; cheaper viable alternatives; pop-up windows in application.

ExpressVPN 1-Year Plan $8.32/month
ExpressVPN 6-Month Plan $9.99/month
ExpressVPN 1-Month Plan $12.95/month
www.expressvpn.com

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LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Mismatched components
> Donating desktops
> Money-no-object monitors

Mad with power

I've been a subscriber to *Maximum PC* for roughly 20 years and this is the first email I've sent. However, I felt compelled to chime in after having some critical feelings about certain contemporary PC and technology trends and topics.

The first one is my HUGE agreement with Jeremy Laird on his critical take on excess power consumption that is now exponentially accelerating (June 2022). He nailed it on the head as something that needs to be circulated and pushed back against, not just from Nvidia but Intel, AMD, and anyone else that is trying to hold performance gains SUPERFICIALLY, while significantly increasing TDP and TGP. All of this excess power draw and heat generation is strangely happening at a time when energy prices are through the roof, the electric grid is more strained than ever, and most world leaders are making aggressive pushes toward mitigating climate change. Current world events and upcoming policies and legislation show that it's time to start tapering off power consumption on virtually every kind of device. Performance-per-watt marketing needs to ramp up again, not purely performance marketing.

I also wanted to say how awesome your feature 'State of the GPUnion address' was in that same issue. I really appreciated all the research and found it interesting to see how the older GPUs compare today. AMD has shown the ability to gain performance relative to Nvidia over time, and while Bulldozer never did actually pan out, sometimes its forward-looking approach benefits users who keep their GPUs for several years.

Lastly, your 'MSI Special Single Manufacturer Build' (June 2022, page 66) was a neat article, but I found the Core i9-12900K "total overkill" as you mentioned when compared to the RTX 3050. I realize that was all Intel provided, but it just threw the whole concept out the window for me. The build would have just tipped over $2K with a 12700K, a much more reasonable high-end CPU, if not also overkill in this particular build (namely with the RTX 3050 "limitation").

Rant over! I would really like to see more articles with other big-name manufacturers, such as Asus and Gigabyte.
Keep up the great work on *Maximum PC*! – **D. Swanson**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks to you and all the others who write in every month and offer feedback like this—I know for me, and for all of the writers, it makes the hard work worthwhile. I'm really glad you enjoyed both Jeremy and Jarred's articles, as you say, they're the result of a lot of research.

When I saw all of Jarred's spreadsheets for the GPU comparison, I was worried that the amount of work involved would blow the entire month's freelance budget, but it's been an ongoing labor of love for him based on reviewing practically every graphics card released over the past ten years.

I completely agree with you (and Jeremy) about the seemingly never-ending increase in power demands for GPUs. Your idea of a power efficiency rating or comparison is astute, and something the industry should be adopting in line with all the other sustainability efforts being made. I hope to build on this with a proper feature soon, as it's even more important at a time when, as you mention, energy price increases show no signs of slowing.

Your final point on the pairing of an Intel Core i9-12900K and an Nvidia RTX 3050 is correct, and to reiterate, not a match I'd recommend in the real world unless you're doing CPU-heavy tasks and some light gaming. One thing I've found since joining *Maximum PC* is that it's sometimes difficult to get the components we request. It's something I encountered again in this month's cover build, where it was impossible to get a micro-ITX motherboard.

Thankfully, we have good friends at our sister titles such as *PC Gamer*, who have been very helpful, and I'm doing more to reach out to the relevant manufacturers in order to get the parts we need. I'm also constantly surprised

↘ submit your questions to: editor@maximumpc.com by what's in the *Maximum PC* storage cupboard, with entire systems that we've built before just ripe for the picking—like the SSDs I used in my cover build this month. Anyway, it's a situation I'm well aware of and working on resolving, so thanks again for your feedback.

Charity case

I've been an avid reader of *Maximum PC* for roughly ten years. I'm always eager to follow the upgrades and builds suggested in the magazine, but can rarely justify them as my current PC is fine and can do what I need it to do, including gaming. I believe I'd be much more willing and frequent to do the fun builds if I could get my older rig to people, families, and/or organizations in real need if they could make use of it.

I'm not interested in attempting to sell or work through scammers on online marketplaces and would feel better knowing my old rig is making a difference somewhere. Is *Maximum PC* aware of any valid organizations that take in used computers and provide them to people in need, or perhaps something more direct or local, ideally where things can be dropped off in nearby communities and don't need to be shipped?

A *Maximum PC* reader's computer should always be in great condition and fast enough to do what's needed in everyday lives. We just want to upgrade (and have more rationalization to do so)! **–C. Fahrner**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Fantastic question, and one I needed to look into myself for an answer. Now, I'll caveat this by saying I've not used any of these services personally, so I can't recommend them, but they're at least options worth checking out. Top of the list is www.computerswithcauses.org, which has offices in all of the major states, accepts all sorts of computer hardware, and your donations are tax-deductible, with hardware going to schools, the elderly, and veterans, among others.

Also consider www.digitunity.org, which aims to bridge the digital divide by matching equipment donors with people who need access, whether that's to apply for jobs, study in education, or anything else. Its website allows you to search for pre-qualified organizations who have what you're looking for, connect, and then the equipment can be collected from you or delivered.

Thanks again for an excellent question and I hope it helps someone out!

Monitor Money

I've been a long-time subscriber of *Maximum PC* and the advice you've given me has been invaluable. However, I have a bit of a quandary. Although I must admit to being fortunate to be in this position, I have an ancient but superb monitor, the NEC MultiSync LCD3090WQXi, which despite being purchased nine years ago is almost 2K resolution (2,560 x 1,600 pixels). Unfortunately, it's finally showing wear and tear and I'm looking for another one. I mainly use my computer for gaming and have an Intel Core i5-12600K CPU, Nvidia RTX 3080 Ti video card, and 32GB of RAM.

My problem is that I purchased the Asus ROG Swift PG32UQX monitor for about $3,000 and I'm not impressed at all (except for it being a bit brighter and having HDR). Certainly, for that price, I expected my socks to be well and truly blown off!

Therefore I ask you, is there a better monitor available? I would have purchased something like the Samsung Odyssey Neo G9, but the resolution isn't impressive and I wanted 4K. I was thinking about the Alienware OLED? I would appreciate your advice. Money's no object and also I don't usually play competitive games. Thanks! **–R. Kleinhaus**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: When reading your letter, my mind immediately went to the monitor you later suggested—the Dell Alienware AW3423DW. Reviewed in our June 2022 issue, we described it as "likely the best [gaming monitor] we've ever seen".

The problem is, it's only a 1440p display (albeit an ultra-wide one), which isn't ticking the 4K box you seem to desire. Another challenge is you've gotten used to the larger screens over the last decade, with 30-inch and then 32-inch. If you want to go large, then the Philips Momentum 558M1RY is worth checking out—it's a massive 55-inch, 120Hz display reasonably priced at $1,500.

Personally, I've been using LG monitors for the last couple of years, and recommend the LG 27GN950-B. It's only 27-inch but offers incredible detail for that 3080Ti. I've also coveted the Samsung Odyssey Neo G9 ever since I saw it at CES earlier this year. What it lacks in vertical resolution, it makes up for with its mammoth horizontal scale.

Whatever you do though, try and get into a store where you can take a look at these monitors before buying. It's always worth seeing them in real life before making a big purchasing decision, and this is something that you're going to be spending a long time looking at!

Graphical Fixes

I absolutely LOVED the feature on the GPU roundup, putting the recent cards in context. That was incredible. So incredible, in fact, it certainly opens up the idea of trying to do the same for SSDs, and CPUs, for example. One could easily come up with a few cool ways to compare generations and visually display them in a similar fashion. I also loved the in-depth article on monitor technology.

Keep up the good work!

–A. Arnesen

I just received my June issue of *Maximum PC* and was thrilled to see a feature I had requested actually made it into print—the multi-generational graphics card roundup. With all the turmoil in graphic card availability over the past 18 months, it's good to get a real idea of when it's time to upgrade and when splurging on an overpriced card is only going to soothe a fear of missing out.

I was disappointed to see that my long-suffering GTX 970 ranked so low, although not particularly surprised in modern games. It still manages over 60fps in *Overwatch* at 2560x1440, while driving a second monitor for Discord, but I have no doubt *Flight Simulator* would bring it to its knees. I guess I'll sit back and wait for the 40xx cards to roll out. **–S. Latta**

EDITOR-IN-CHIEF, GUY COCKER, RESPONDS: Thanks for the GPU feature love—it really is great to be able to see at a glance how yours stacks up in 2022.

I love the idea of doing this for SSDs and CPUs—the latter would be feasible from one of our CPU specialists, and I'm trying to get more SSDs in for builds that we could do a comparison with. Watch this space!

THE BUILDS

THIS MONTH'S STREET PRICES...

BUDGET

AFTER THE HEAVY INFLUX of new components to our Intel budget build last issue, including a new CPU and GPU, we kept the changes to a minimum this time around. The only changes of note here are a new B660 motherboard from ASRock, swapped in to trim the overall price without sacrificing performance, and a new SSD from PNY which should exactly match the MSI Spatium M450 in the AMD system in terms of performance. The AMD build gets a new motherboard, snapping up Gigabyte's B550 Aorus Elite for $125. It's $5 more expensive than the previous mobo, but the Aorus Elite is the superior board so it's a fair tradeoff. As a result, both of our budget-build motherboards now have RGB lighting, an unintended but not unwelcome addition.

A sale saw the price of our Ryzen 5 5600X processor drop by $20, while the Core i5-12600 held steady at $230, making the AMD chip currently the cheaper option—although the Intel CPU still has an edge in overall performance. Another sale brought MSI's Mech edition of the RX 6600 XT GPU down below $400, making it currently the closest 6600 XT to the card's original retail price. It replaces an XFX GPU, which didn't change in price.

We've been doing our research regarding the huge number of memory brands currently saturating the budget RAM market. Though we haven't used Oloy and Mushkin RAM here in the past, these two brands are considered trustworthy, if not on the same level as market leaders Corsair, Crucial, and G.Skill. We'd recommend opting for the Redline series if you choose to buy Mushkin memory, as it's a popular choice among overclockers. Other brands, like Klevv and V-Color, are probably best avoided. Our investigation ground to a halt, though, once we realized that the Corsair Vengeance LPX and G.Skill Ripjaws V kits we already had in these builds were still the best two 2x 8GB memory kits available right now at that speed and latency. Oh well!

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	550W Asus TUF Gaming 80+ Bronze	$50	
Mobo	Gigabyte B550 Aorus Elite AM4 **NEW**	$125	
CPU	AMD Ryzen 5 5600X	$209	
GPU	MSI Mech Radeon RX 6600 XT 8GB **NEW**	$379	$390
RAM	16GB (2 x 8GB) Corsair Vengeance LPX CL16 @ 3600MHz	$78	
SSD	500GB MSI Spatium M450 PCIe 4.0 M.2 SSD	$50	
HDD	4TB Seagate Constellation ES 7200	$47	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	

Approximate Price: $1,053 / $1,064

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Corsair 4000D Airflow	$95	
PSU	550W XPG Pylon 80+ Bronze	$60	
Mobo	ASRock B660 Pro RS LGA 1700 **NEW**	$140	
CPU	Intel Core i5-12600	$230	
GPU	Gigabyte Eagle OC GeForce RTX 3060 8GB	$329	$460
RAM	16GB (2 x 8GB) G.Skill Ripjaws V CL16 @ 3600MHz	$70	
SSD	500GB PNY CS2140 PCIe 4.0 M.2 **NEW**	$55	
HDD	4TB Seagate Constellation ES 7200	$47	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	

Approximate Price: $1,046 / $1,177

MID-RANGE

Z690 MOTHERBOARDS face an uptick in price, even those configured for DDR4 memory rather than the pricier DDR5. The Intel mid-range build mimics its budget cousin with a Pro RS mobo from ASRock but with the more powerful Z690 chipset instead of B660. The AMD also benefits from a new ASRock motherboard, the trusty X570 Steel Legend, also changed for price reasons. We're sticking with EVGA for both power supplies but are swapping out the G5 model of the SuperNOVA 750 for the GT version in the AMD system. This PSU is fully modular and packs the same 80+ Gold rating as the G5 it replaces and the GA found in the Intel machine. Reduced from $140 to $75, it's a significant saving.

While the Intel Core i7-12700F didn't change in price this month, the Ryzen 7 5800X CPU at the core of our mid-range AMD system did see a reduction. The stellar deal on XFX's SWFT319 RX 6800 XT graphics card from last month is now gone, so we've shifted back over to ASRock's Phantom Gaming D model instead.

We opted to provide a small upgrade to the Intel machine, namely a jump from the RTX 3070 to the RTX 3070 Ti. The card we chose is the Asus TUF Gaming, currently the best-value 3070 Ti on the market when buying new. This brings both pricing and performance closer between the two mid-range systems, with average performance on the 3070 Ti now outstripping the AMD.

A price drop on the Enermax Aquafusion liquid cooler in the Intel build shaves $30 off the price. We've also upgraded the SSD in the Intel build to the Pro LPX version of the Corsair MP600 drive, which is a little more expensive but should see speeds closer to the Samsung 980 Pro previously found in the AMD system. That SSD is gone this month too, though, with a sale ending, it no longer offered the same level of value for money. In its place is the WD Black SN850, sitting close to the MP600 Pro LPX in terms of both cost and performance.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$154	
PSU	750W EVGA SuperNOVA 750 GT 80+ Gold **NEW**	$75	
Mobo	ASRock X570 Steel Legend AM4 **NEW**	$150	
CPU	AMD Ryzen 7 5800X	$309	
Cooler	Raijintek Orcus 240 RBW ARGB	$75	
GPU	ASRock Radeon RX 6800 XT Phantom Gaming D 16GB **NEW**	$649	$800
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz	$160	
SSD	500GB WD Black SN850 NVME M.2 PCIe 4.0 SSD **NEW**	$95	
HDD	4TB Seagate Constellation ES 7200	$47	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	
Approximate Price:		**$1,734 / $1,885**	

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Lian Li PC-O11-Dynamic	$154	
PSU	750W EVGA SuperNOVA 750 GA 80+ Gold	$75	
Mobo	ASRock Z690 Pro RS LGA 1700 **NEW**	$190	
CPU	Intel Core i7-12700F	$313	
Cooler	Enermax Aquafusion 240 ARGB 240mm	$60	
GPU	Asus TUF Gaming GeForce RTX 3070 8GB **NEW**	$599	$700
RAM	32GB (2 x 16GB) Corsair Vengeance RGB RT CL16 @ 3600MHz	$160	
SSD	500GB Corsair MP600 Pro LPX M.2 PCIe 4.0 **NEW**	$90	
HDD	4TB Seagate Constellation ES 7200	$47	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	
Approximate Price:		**$1,708 / $1,809**	

TURBO

HIGH-WATTAGE PSUS are on the rise, with the EVGA SuperNOVA P6 and the Corsair HX850 rising to match price at $170 since we introduced our new 80+ Platinum rule for the turbo builds. They are some of the best-value power supplies in the 850W range, without resorting to Chinese manufacturers such as Segotep.

As CPU and GPU prices continue to fall, we've chosen to put a bit more funding into the motherboard department of our turbo builds. After setting a $300 price limit (because nobody really needs to spend more than that on a motherboard), we settled on the MSI MPG Z690 Edge Wi-Fi for the Intel build, and the incredibly stylized ASRock X570 Taichi for the AMD machine. Both of these offer superior board thermals compared with the previous mobos as well as some features the old boards lacked.

With a new generation of Ryzen looming, the 5950X processor continues to drop in price, now costing $549. This puts it below the i9-12900K when it comes to cost, although the Intel chip offers superior performance. The release of new '50' variants of the Radeon RX 6000 series of GPUs also saw us upgrade from the RX 6900 XT to ASRock's OC Formula RX 6960 XT, currently selling at RRP—a rarity for a high-end GPU right now. Its performance still lags behind the powerhouse RTX 3090, but it's a lot cheaper.

The AMD system gets a new three-fan AIO cooler, the ML360 Illusion from CoolerMaster. Both machines keep their WD Blue 6TB hard drives, but the AMD machine gets a new SSD, with the Gigabyte 7000s drive up in price, we've opted for the 1TB version of the WD Black SN850 also seen in the mid-range AMD build. This brings pricing more in line between the two turbo builds.

Although Corsair's Vengeance DDR5 memory was on sale this month, it's still more expensive than the DDR4 RAM from G.Skill in the AMD build and lacks the RGB lighting. We weren't able to make any other significant savings in the Intel turbo build this month, so with the Ryzen 9 price drop and RTX 3090 prices remaining high, it's still more expensive than the AMD rig.

AMD INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$188	
PSU	850W EVGA SuperNova P6 80+ Platinum	$170	
Mobo	ASRock X570 Taichi AM4 **NEW**	$300	
CPU	AMD Ryzen 9 5950X	$549	
Cooler	CoolerMaster MasterLiquid ML360 Illusion 360mm **NEW**	$163	
GPU	ASRock Radeon RX 6900 XT Phantom Gaming D 16GB	$1,099	$1,100
RAM	64GB (2 x 32GB) G.Skill Trident Z Neo DDR4 @ 4000MHz CL18	$320	
SSD	1TB WD Black SN850 M.2 PCIe 4.0 **NEW**	$136	
HDD	6TB WD Blue 5400 HDD	$70	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	

Approximate Price: $3,015 / $3,016

INTEL INGREDIENTS

PART		PRICE	STREET PRICE
Case	Phanteks Enthoo Pro 2 Tempered Glass	$188	
PSU	850W Corsair HX850 80+ Platinum	$170	
Mobo	MSI MPG Z690 Edge Wi-Fi DDR5 LGA 1700 **NEW**	$296	
CPU	Intel Core i9-12900K	$599	
Cooler	MSI MAG CoreLiquid 360R V2 360mm	$140	
GPU	Gigabyte GeForce RTX 3090 Gaming OC 24GB	$1,500	$1,700
RAM	64GB (2 x 32GB) Corsair Vengeance DDR5 @ 5200MHz	$470	
SSD	1TB Gammix Gaming S70 M.2 PCIe 4.0 SSD	$126	
HDD	6TB WD Blue 5400 HDD	$70	
OS	Windows 10 Home 64-bit OEM (Windows 11 Compatible)	$20	

Approximate Price: $3,579 / $3,779

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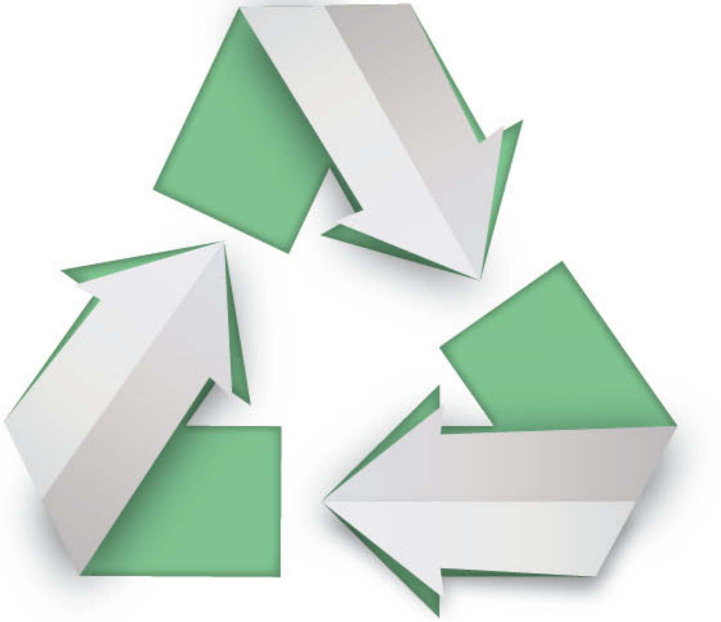

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